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SEASONAL FLUCTUATIONS IN NUMBERS OF MICRO-ORGANISMS AND NITRATE NITROGEN IN AN ALBERTA SOIL *

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Experiments were started by the Soils Department of the University of Alberta in 1923, in order to study certain of the underlying principles of rotation of crops, or of crop succession, and to study the effect upon soils of the popular practice of summerfallowing. We all know that the largest possible yields are seldom obtained when one crop is grown year after year on the same land; but we are still far from a complete understanding of the nature of the beneficial effect of crop rotation, and from knowing what succession of crops, or rotation of crops, will give the best possible yields in various circumstances. A great deal of experimental work on crop rotations has been done in our Canadian prairie provinces, and elsewhere, at the different agricultural experiment stations. Nearly all of these experiments have consisted of comparisons of yields obtained from different rotations throughout a long period of years. It was felt that a different idea of the problem of crop rotations should be obtained, and suitable rotations might, perhaps, be forecast or suggested, and much time saved, if we knew what effects a given crop has upon the soil's composition, and particularly upon the soluble constituents of the soil.

Our earlier studies, started at Edmonton in 1923, were largely confined to soluble nitrogen and moisture. True, nitrogen is only one of seven or more essential elements which come from the soil, but plants nearly always utilize larger quantities of nitrogen than of any other one of these seven essential elements. We know that the quantities of water-soluble Ca, K, Mg, P, S, etc., also vary under different crops and throughout the season, but the variations are usually smaller than that of nitrogen, and in the same direction as that of nitrogen (8). We have therefore taken soluble nitrate nitrogen as the index of these fluctuations.

Comparisons were made of the quantities of soluble nitrogen in soils under various crops, as well as in fallow land. The findings might be summarized in part by stating that whereas fallow land usually contained most soluble nitrate nitrogen, the perennial crop soils, and particularly the grass crop soils, usually contained least. The soils supporting the ordinary grain crops, such as wheat and oats, contained intermediate amounts of soluble nitrogen. Another interesting point observed was that soluble nitrogen accumulated more rapidly in a fallow following clover or alfalfa than in a fallow following grasses or grain, or other non-legume crops. This helps

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to explain why better yields are usually obtained following clovers or alfalfa than following grains or grasses; plant food is formed more rapidly in the soil following the legume crop. The actual nitrate and moisture data obtained in these earlier experiments will not be given in this paper, as they may be obtained from previous publications (12, 13).

A study of seasonal fluctuations in numbers of microorganisms and nitrate nitrogen in an Edmonton soil was undertaken because it was felt that fresh information must be gained by such a study, first, regarding the general groups and numbers of the soil microorganisms and, second, regarding the effect of different crops and cultural practices upon the number and activity of these organisms.

It was concluded from some of the earlier determinations of numbers of microorganisms in soil by bacteriologists that no definite relationship between the total number of bacteria and the fertility of the corresponding soil could be recognized. Russell and Appleyard (5), however, found the curves for bacterial numbers, nitrate content, and carbon dioxide in the soil to be sufficiently similar to justify the view that all the phenomena are related. Waksman (9) also states that crop production ran nearly parallel with the numbers of microorganisms, from a series of plots, developing on plates.

The method adopted in our experiments might be described as a modification of the method of Chemical Analysis in Conjunction with Bacterial Counts used largely at Rothamsted (6). Four plots located in the University Field Crops Department experimental field at Edmonton, were chosen for these studies in both 1927 and 1928, the plots consisting of fallow, wheat, alfalfa, and grass. The soil in these plots is a fairly uniform, deep, black loam, rich in organic matter, containing about 0.6 per cent nitrogen, underlaid by a clay subsoil, and almost neutral in reaction. The nitrate nitrogen and moisture content of surface, subsurface, and subsoil in the four plots were determined at intervals of about two weeks throughout the main growing season, and samples of surface soil were also taken in sterilized containers at the same time, or at similar intervals, for determination of numbers of bacteria, fungi and actinomycetes.

The percentages of moisture, in both 1927 and 1928, were, on the average, highest in the fallow land, followed in descending order by wheat, alfalfa, and grass. This order was very regular in the later part of the growing season (see Figures 1 and 2). These figures represent percentages of moisture in the surface seven inches of soil, based on the dry weight of soil. It was previously stated that this soil is exceptionally rich in organic matter and, consequently, it will be observed that it has a very high moisture holding capacity.

The quantities of nitrate nitrogen, in both years, were also, on the average, highest in fallow land, followed in descending order by wheat, alfalfa, and grass (see tables 1 and 2, and Figs. 1 and 2). The quantities were markedly lower under alfalfa and grass than under fallow and wheat, as observed in previously reported experiments (12, 13). The nitrate determinations were made by Harper's modification of the phenol disulphonic acid method (3), and the figures represent pounds of nitrate nitrogen per acre to the depth of forty inches.

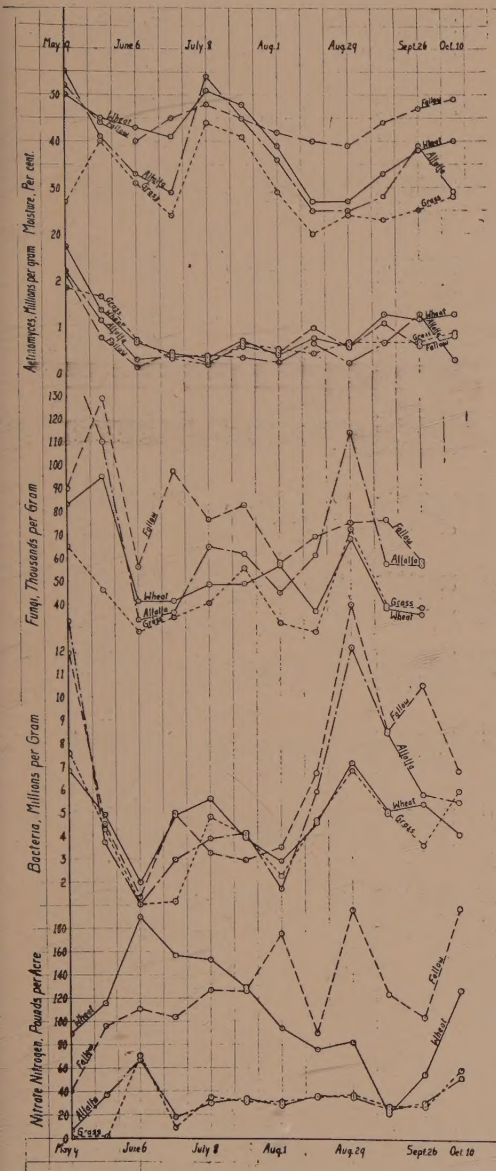


FIG. 1—1927

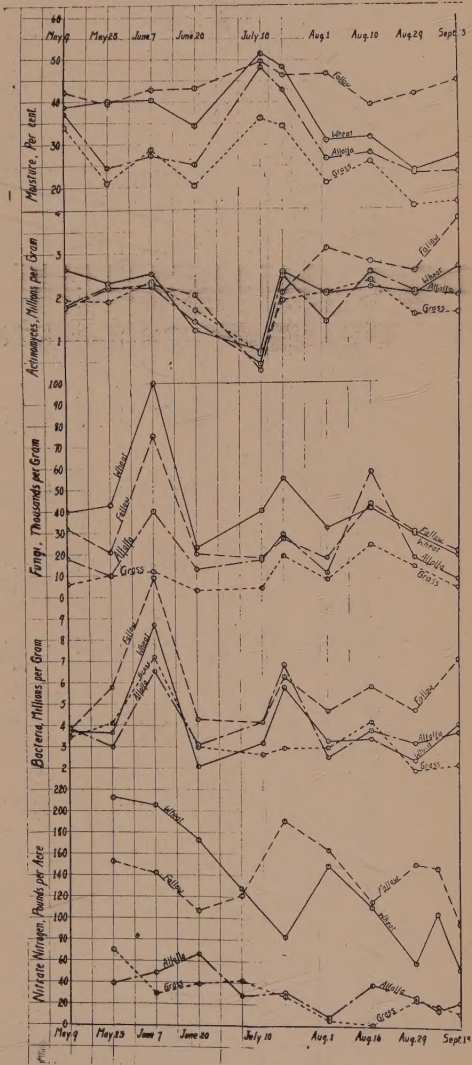


FIG. 2—1928

Seasonal fluctuations in moisture, nitrate nitrogen, and numbers of microorganisms, under fallow, wheat, alfalfa, and grass.

TABLE 1.—Seasonal fluctuations in moisture, nitrate nitrogen, and numbers of microorganisms, under fallow, wheat, alfalfa, and grass, in 1927.

PLOT	May 9	May 23	June 6	June 20	July 8	July 18	Aug. 1	Aug. 15	Aug. 29	Sept. 12	Sept. 26	Oct. 10	Av.
<i>Moisture in Upper Seven Inches of Soil: Per cent.</i>													
A-7 Fallow following oats	52	44	40	45	48	45	42	40	39	44	47	49	45
B-9 Wheat following fallow	50	45	43	41	51	48	39	27	27	33	38	40	40
A-5 Alfalfa	55	41	33	29	54	45	36	25	25	28	39	29	37
Grass	27	40	31	24	44	41	29	20	24	23	25	28	30
<i>Nitrate Nitrogen in Upper Forty Inches of Soil: Pounds per Acre.</i>													
A-7 Fallow following oats	41	96	111	104	127	126	175	90	195	123	103	196	124
B-9 Wheat following fallow	90	116	190	157	153	129	94	76	82	22	55	126	107
A-5 Alfalfa	7	37	67	18	30	34	28	36	35	25	31	52	33
Grass	Trace	Trace	71	9	35	31	31	35	37	28	28	59	30
<i>Bacteria in Upper Seven Inches of Soil: Millions per Gram.</i>													
A-7 Fallow following oats	11.89	4.46	1.34	4.97	3.21	2.86	3.47	6.63	13.86	8.40	10.32	6.66	6.50
B-9 Wheat following fallow	6.80	4.90	1.97	4.90	5.57	3.86	2.87	4.50	7.07	4.96	5.25	3.96	4.74
A-5 Alfalfa	13.28	3.72	1.01	2.97	3.84	4.07	1.67	5.83	12.01	8.35	5.65	5.32	5.64
Grass	7.55	4.25	1.02	1.14	4.77	3.97	2.21	4.61	6.73	4.90	3.50	5.79	4.20
<i>Fungi in Upper Seven Inches of Soil: Thousands per Gram.</i>													
A-7 Fallow following oats	90	129	56	97	76	82	57	68	74	75	57	78	78
B-9 Wheat following fallow	83	95	41	41	48	48	56	36	67	37	34	53	71
A-5 Alfalfa	150	110	33	36	64	61	44	60	113	56	55	71	71
Grass	65	46	28	34	40	55	31	27	71	38	37	43	43
<i>Actinomycetes in Upper Seven Inches of Soil: Millions per Gram.</i>													
A-7 Fallow following oats	2.12	.77	.13	.45	.24	.57	.42	.96	.53	1.04	.54	.75	.71
B-9 Wheat following fallow	2.74	1.37	.66	.42	.33	.70	.38	.74	.55	1.23	1.11	1.23	.95
A-5 Alfalfa	2.21	1.14	.30	.35	.38	.34	.23	.62	.20	.61	1.22	.23	.65
Grass	1.85	1.66	.72	.32	.19	.63	.51	.41	.64	.62	.63	.83	.75

TABLE 2.—Seasonal fluctuations in moisture, nitrate nitrogen and numbers of microorganisms, under fallow, wheat, alfalfa, and grass, in 1928.

PLOT	May 9	May 23	June 7	June 20	July 10	July 18	Aug. 1	Aug. 16	Aug. 29	Sept. 6	Sept. 13	Av.
<i>Moisture in Upper Seven Inches of Soil: Per cent.</i>												
A-6 Fallow following oats	42	39	43	43	50	46	47	39	42		45	44
A-7 Wheat following fallow	39	40	40	34	51	48	31	32	24		27	37
A-5 Alfalfa	37	24	27	25	48	43	27	28	23		23	30
Grass	34	21	29	20	36	34	21	26	16		17	25
<i>Nitrate Nitrogen in Upper Forty Inches of Soil: Pounds per Acre.</i>												
A-6 Fallow following oats	153	142	107	121	191		164	115	150	147	96	139
A-7 Wheat following fallow	213	206	173	128	83		149	110	59	105	54	128
A-5 Alfalfa	39	49	67	28	31		8	38	27	16	23	33
Grass	70	29	39	42	27		5	Trace	25	19	13	27
<i>Bacteria in Upper Seven Inches of Soil: Millions per Gram.</i>												
A-6 Fallow following oats	3.78	5.79	10.90	4.28	4.22	6.24	4.66	5.79	4.66		7.06	5.74
A-7 Wheat following fallow	3.71	3.64	8.70	2.07	3.16	5.75	3.23	3.37	2.33		4.02	4.00
A-5 Alfalfa	3.84	3.00	6.53	3.07	4.22	6.82	2.50	3.74	3.13		3.65	4.00
Grass	3.43	4.09	7.18	3.00	2.65	2.93	2.94	4.15	1.88		2.11	3.44
<i>Fungi in Upper Seven Inches of Soil: Thousands per Gram</i>												
A-6 Fallow following oats	32	21	75	20	18	27	18	43	30		20	30
A-7 Wheat following fallow	40	43	100	23	40	55	32	41	29		19	42
A-5 Alfalfa	18	10	40	13	17	29	11	58	18		8	22
Grass	6	10	12	3	4	19	8	24	14		4	10
<i>Actinomyces in Upper Seven Inches of Soil: Millions per Gram.</i>												
A-6 Fallow following oats	1.75	2.20	2.28	2.03	.28	2.08	3.08	2.77	2.54		3.78	2.28
A-7 Wheat following fallow	2.64	2.31	2.52	1.21	.72	2.55	2.06	2.18	2.01		2.64	2.08
A-5 Alfalfa	1.78	2.21	2.22	1.41	.44	2.46	1.39	2.52	2.08		1.97	1.85
Grass	1.92	1.88	2.33	1.68	.68	1.90	2.06	2.32	1.53		1.56	1.79

The numbers of bacteria were somewhat variable, and the differences between fallow land and land under different crops were not as great nor as regular as might have been expected. In both seasons, however, the numbers of bacteria were, on the average, highest under fallow and lowest under grass, with wheat and alfalfa land intermediate; and this is probably the normal order.

The seasonal averages for the different plots varied from about three and one-half to about six and one-half million bacteria per gram of dry soil. The numbers are considerably smaller than obtained at Rothamsted, in England, as Thornton (7) states that about twenty million bacteria per gram is now considered a fair average number. The numbers obtained at Edmonton are also smaller, apparently, than obtained by Lochhead (4) at Ottawa, but similar to seasonal averages obtained by Waksman (9) in a New Jersey Sassafras loam, which received no fertilizer, or only mineral fertilizers. Waksman observed, however, that applications of barnyard manure caused a marked increase in the number of bacteria present. Nitrification proceeds rapidly in the Edmonton soil, as observed also in previous experiments (12, 13), and it is evidently not only the number of soil organisms which is important, but also their activity. Furthermore, it must be realized, as pointed out by a number of soil bacteriologists, that not all of the soil bacteria will grow upon any one artificial medium, and that the numbers actually present are much larger than shown by this plate count method. However, the method should indicate the *relative* numbers of bacteria present under the different crops and cultural conditions.

Composite samples of the surface seven inches of soil were taken for these determinations. In nearly all cases a dilution of 1:100,000 was used, and the plates were incubated at room temperature and counted at the end of seven days. A beef peptone agar medium recommended by Fred (2) was used, and all plating was done in triplicate. The averages of these three plates were used to estimate the numbers of bacteria present, per gram of dry soil.

The work of Cutler, Crump, and Sandon at Rothamsted (1) showed that the bacterial numbers vary considerably from one day to the next. The extent of the daily fluctuations in Edmonton soil has not been determined, but it is probably smaller than at Rothamsted, in view of the fact that the total number of bacteria is generally much smaller than at Rothamsted. Superimposed on these daily fluctuations are the great seasonal changes in bacterial numbers, observed by Russell at Rothamsted, and observed elsewhere. One object of the experiments reported in this paper has been to measure these larger seasonal changes. A well marked increase in the spring and fall has been observed in more humid climates, but it seemed doubtful if we could expect such a well marked increase in the fall in Alberta, as the late summer and fall weather is normally rather dry, whereas the late spring and early summer weather is usually quite wet at Edmonton. The rainfall varies considerably from season to season, and the curves for 1928 do not resemble the 1927 curves at all closely. In both seasons, however, the bacterial numbers attained a spring maximum, the counts for May 9, 1927, and June 7, 1928, being unusually high.

The numbers of fungi were very much smaller than the numbers of bacteria, but usually varied in the same direction as the bacterial numbers. This correlation was quite apparent in both 1927 and 1928, as shown in Figures 1 and 2. In both seasons, it will be observed, the numbers of fungi were, on the average, lowest under grass. The fungi were determined by Waksman's acid agar plate count method (10) and the medium apparently produced consistent results.

The numbers of actinomyces were also determined by the plate count method, and for this purpose the dextrose agar medium recommended by Waksman was used (11). The actinomyces numbers were, on the average, considerably smaller than the bacterial numbers, and varied somewhat irregularly. According to Russell, however, it is doubtful whether counting methods for actinomyces are reliable. The correlation between rise and fall in numbers of bacteria and fungi is quite evident in Figures 1 and 2, but there is little evidence of correlation between these and actinomyces.

Russell observed in certain experiments at Rothamsted that the seasonal nitrification curve tended to follow the seasonal curve for bacterial numbers, with a lag of about two weeks in the curve for nitrification. In the Edmonton experiments the fluctuations in nitrate nitrogen did not correspond closely to fluctuations in numbers of bacteria and fungi, or actinomyces. It will be observed, however, that the highest percentages of moisture and nitrate nitrogen in both seasons are to be found in fallow land, and the lowest in grass land, and that the average number of bacteria in both seasons was greatest in fallow land and least in grass land.

The character of the organic matter undoubtedly influences the relationship of nitrification to bacterial numbers. If the organic matter undergoing decomposition were highly nitrogenous one would expect the nitrification curve to follow the bacterial number curve more closely than if the organic matter were mainly carbohydrates, particularly in fallow land. In cropped land the absorption of nitrates by the growing plants would naturally disturb this relationship. Even in fallow land the nitrate curve fluctuates, and high concentrations are frequently followed by decreases. Such decreases may be due to leaching of nitrates in some cases, but it is probable that they are usually due to absorption of nitrates by microorganisms other than nitrifying bacteria.

SUMMARY

The fluctuations in nitrate nitrogen did not correspond closely to fluctuations in numbers of bacteria and fungi, or actinomyces. In both seasons, however, the highest percentages of moisture and nitrate nitrogen were found in fallow land, and the lowest in grass land, and the average number of bacteria was greatest in fallow land and least in grass land.

The numbers of fungi were very much smaller than the numbers of bacteria, but usually varied in the same direction as the bacterial numbers.

The actinomyces numbers were, on the average, considerably smaller than the bacterial numbers, and varied somewhat irregularly.

The numbers of bacteria present were generally much smaller than at Rothamsted, and smaller, apparently, than in some of the more humid areas

of eastern North America. In both seasons the bacterial numbers attained a spring maximum.

In previously reported experiments it was found that whereas fallow land at Edmonton usually contained most soluble nitrate nitrogen, and soils supporting the ordinary grain crops contained intermediate amounts, the perennial crop soils, and particularly the grass crop soils, usually contained least. It was also observed that soluble nitrogen usually accumulated more rapidly in a fallow following clover or alfalfa than in a fallow following grasses or grains, or other non-legume crops.

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STUDIES OF WATER ABSORPTION AND GERMINATION WITH VARIETIES OF *TRITICUM VULGARE* AND *T. DURUM* *

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INTRODUCTION

It is a well known fact that common wheats (*Triticum vulgare*, Vill.) germinate much better than durumms (*T. durum*, Desf.) under seed laboratory conditions, although only one reference (28) to this can be found. Because of the small amount of available data published, summaries were made from the germination records of the Minnesota State Seed Laboratory and of the Dominion Seed Branch Laboratory, Winnipeg, Man.

At the Minnesota laboratory, in the 1926 crop year, 114 samples of common wheat averaged 94.3 per cent germination in an average duration test of 5.9 days, while 63 samples of durum wheat averaged 83 per cent germination in 7.4 days. In the 1927 crop year 58 common wheat samples averaged 95.4 per cent germination in 5.4 days and 48 durum wheat samples averaged 85.3 per cent germination in 7.9 days.

At the Winnipeg laboratory, in the 1925 crop year, the common wheat samples germinated, on the average, 6 per cent higher than the durumms, in 1926 about 3 per cent higher and in 1927 about 9 per cent higher.

These data indicate that not only do the common wheats have a higher final germination, but they also have a higher rate of germination.

Seed in the resting condition may have all the materials necessary for germination except water and oxygen. The process of germination, essentially a speeding up of the physiological processes of the young plant, is preceded by, and accompanied by, the absorption of water. It is a matter of observation in laboratory practice that the durum wheats require less water than the common wheats in germination. It was thought that this difference might be related to the variations found in germination. This investigation was planned to measure quantitatively the absorption of some common and durum wheat varieties under various conditions and to determine if differences in absorption were to be found between varieties of the two species.

REVIEW OF LITERATURE

Percival (23), in discussing the germination of the naked caryopses of *Triticum monococcum* L., *T. dicoccum* Schr. and *T. spelta* L., with reference to other wheats, stated that sprouting is generally more speedy in these grains on account of the thinner pericarp, which permits of a rapid absorption of water; Dungan (9) found the rapidity of water-absorption in corn to be associated with the rate of germination.

Many of the first workers on absorption seem to have regarded the seed coats as permeable to practically all water-soluble substances. Gola (11) first demonstrated the existence of a selective semipermeable membrane in the seeds of a great many different species. Brown (3) later showed a similar

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membrane in barley, oats, rye and wheat. Schroeder (24) investigated the semipermeable membrane in wheat, and Shull (25) found semipermeable membranes to exist in several of the Gramineae (including wheat) and in representatives of several other families. Shull (26) pointed out that differences in the degree of semipermeability exist. This was confirmed by Denny (8) who, working with detached seed coats, found differences in degree of permeability in members of the same species.

Braun (2), working with wheat, found that a solute like iodine enters the seed over the entire surface, though not uniformly. He found a gradient of permeability to iodine. Permeability to iodine was greatest at the embryo end, diminishing to a minimum near the distal end, then increasing again slightly. Shull and Shull (27) found a similar condition in corn.

Brown and Worley (4) advanced the theory that the rate of water-absorption depended solely upon a chemical phenomenon, in which the semipermeable membrane played a major role. Shull (26) pointed out that the value of the temperature coefficient for water-absorption was too low to support the chemical theory. Shull and Shull (27) found that the temperature coefficient was about the same whether or not the semipermeable membrane was present, leading to the conclusion that "it is improbable that semipermeability is important in determining the rate of absorption of water when supplied as distilled water." They also conclude that the nature of the seed, whether high in fat, protein, or in carbohydrates, though possibly affecting the total amount of absorption, has little to do with the rate of absorption, which "is determined by physical factors largely, with the state of the colloids modifying to a certain extent the rate of water entry."

Other workers in the absorption field, notably Fischer (10), working with animal tissue, MacDougall (17) and MacDougall and Spoehr (18) with plant tissue, have demonstrated a great similarity between water-absorption of these tissues and the water-absorption of certain colloids or colloidal mixtures. Traube and Marusawa (32) found the behavior of starchy seeds in relation to certain electrolytes and non-electrolytes to correspond essentially to that of starch.

Permeabilities, not only of the semi-permeable membrane in the seed coat, but of the individual cell walls, the protoplasmic membrane and the protoplast of the cell itself are further factors in absorption. Stiles (29) gives a rather complete discussion on this subject.

Shull and Shull (27) conclude that "absorption is as complex as many other life processes and involves both physical and chemical factors."

MATERIALS AND METHODS

The samples of wheat used in this investigation were obtained through the courtesy of the Dominion Experimental Stations at Swift Current, Indian Head, Rosthern and Brandon and the Division of Agronomy and Plant Genetics, University of Minnesota. The samples, with the exception of eleven samples from Minnesota, were taken from variety test plots. The eleven Minnesota samples referred to were taken from plots of Marquis and Mindum wheat that were harvested at the usual date of cutting with the binder and on subsequent dates. Apart from these eleven samples, the

varieties at each station were grown under similar conditions, harvested when mature, with similar subsequent treatment and should be comparable.

A detailed description of the samples used is given in table 1.

The method of determining water-absorption was essentially the same as that of Brown, Shull and others. Duplicate lots of one hundred seeds of each sample were counted out. Cracked and broken kernels were discarded. The seed lots were then weighed with a torsion balance having a sensitiveness of 2 mg. The seed lots were put to soak and, at the intervals indicated, were taken out, superficially and uniformly dried and weighed. The water-absorption was calculated as the increase in weight in per cent of the air dry weight. The percentage increases in weight of the duplicates were then averaged. Tap water was used throughout, being applied at a temperature closely approaching that at which the seeds were kept. The water was changed or added as indicated. The time for weighing was included in the total time interval.

In all seed immersion experiments the seeds were placed in shallow china dishes and covered with water to a depth of about 5 mm. In blotter experiments the seeds were placed between double folds of water-saturated blotting paper.

Where comparisons are made between varieties, they are, unless otherwise indicated, between varieties grown at the same station, harvested when mature and quite comparable.

EXPERIMENTAL DATA

PRELIMINARY TEST OF WATER-ABSORPTION OF IMMERSSED SEEDS

In a preliminary experiment to determine a uniform method of treatment and to obtain a general idea of the maximum amount of absorption in wheat, two lots of Marquis (7429) and Mindum (7448) were used. One lot of each was kept at a constant temperature of 20°C. and the other at an alternating temperature of 20°C. for about eighteen hours and 30°C. for about six hours. Four germinating chambers, with temperature manually controlled, were used. Figure 1 illustrates the data obtained.

As will be seen in Figure 1, at 20°C. the increase in weight in Marquis, after being somewhat higher than that of Mindum, is practically the same at the seven-day period and then falls considerably below that of Mindum as the time increases. At the alternating temperature, Marquis maintains the first advantage throughout. The effect of the higher temperature is quite marked in the Mindum sample. The initial increase in weight is decidedly higher than that of 30°C. but at later periods is less and finally falls off decidedly. This is due to a breaking down of the seed coat.

Stiles and Jorgensen (30), working on the storage tissues of potato and carrot, showed that the absorption of water at 40°C. fell off very rapidly after the first few hours. They ascribed this to the breaking down of the protoplasm. In wheat, however, a less rapid decrease in water-absorption would be expected owing to the presence of a non-living semipermeable membrane.

TABLE 1 *Source and description of samples used.*

Source	Lab. No.	Variety	% Germ.*	% Moisture Content †	Weight per 1000 kernels ‡	Remarks
Swift Current, Sask.	7161	Marquis	97	10.9	33.81	Light frost
	7169	Reward	99	10.6	32.16b	Light frost, few green and undersized
	7173	Mindum	98	9.8	43.42	Slight frost damage
	7174	Kubanka	90	10.0	42.72b	Frost, some small and shrunken kernels
	7175	Marquis	93	8.4	35.73	Slightly bleached and shrunken
Rosthern, Sask.	7179	Reward	100	8.3	34.79b	Slightly bleached and shrunken, few green
	7180	Mindum	99	8.0	49.80	Slightly shrunken
	7181	Kubanka	97	8.0	48.54b	Slightly shrunken, trace frost
Indian Head, Sask.	7183	Marquis	98	10.0	32.21	Uniform
	7191	Reward	97	10.0	31.45b	Few shrunken and green
	7192	Mindum	74	9.9	45.93	Uniform, slightly bleached
	7418	Marquis	95	10.0	33.54	Bleached and undersized
St. Paul, Minn.	7419	Reward	94	10.1	34.56b	Bleached, few undersized
	7420	Mindum	81	9.8	46.28	Bleached, some starchy and undersized
	7424	Marquis	57	9.8	33.65	Bleached and shrunken kernels
	7425	Marquis	57	9.9	34.13a	Bleached
	7426	Marquis	90	9.9	33.60a	Bleached
	7427	Marquis	98	9.9	33.06a	Bleached, some undersized
	7428	Marquis	96	10.0	32.26b	Bleached and shrunken
	7429	Marquis	99	10.2	32.78c	Bleached and shrunken
	7430	Marquis	96	10.3	33.88a	100% bleached
	7431	Marquis	93	10.4	32.71a	100% bleached
Brandon, Man.	7448	Mindum	87	9.8	43.84c	Few starchy undersized
	7449	Mindum	77	9.8	44.76a	Few starchy, bleached, few shrunken
	7450	Mindum	74	9.6	44.25a	100% bleached
	7647	Marquis	94	10.2	32.61b	Some green and weathering
	7649	Reward	94	10.1	35.83b	Uniform

* Per cent germination based on average of duplicates.

† The writer is indebted to the Dominion Grain Research Laboratory, Winnipeg, Man., for the moisture determinations.

‡ In weight per 1000 kernels those marked a, b, c, were based on 200, 400 and 600 kernels respectively.

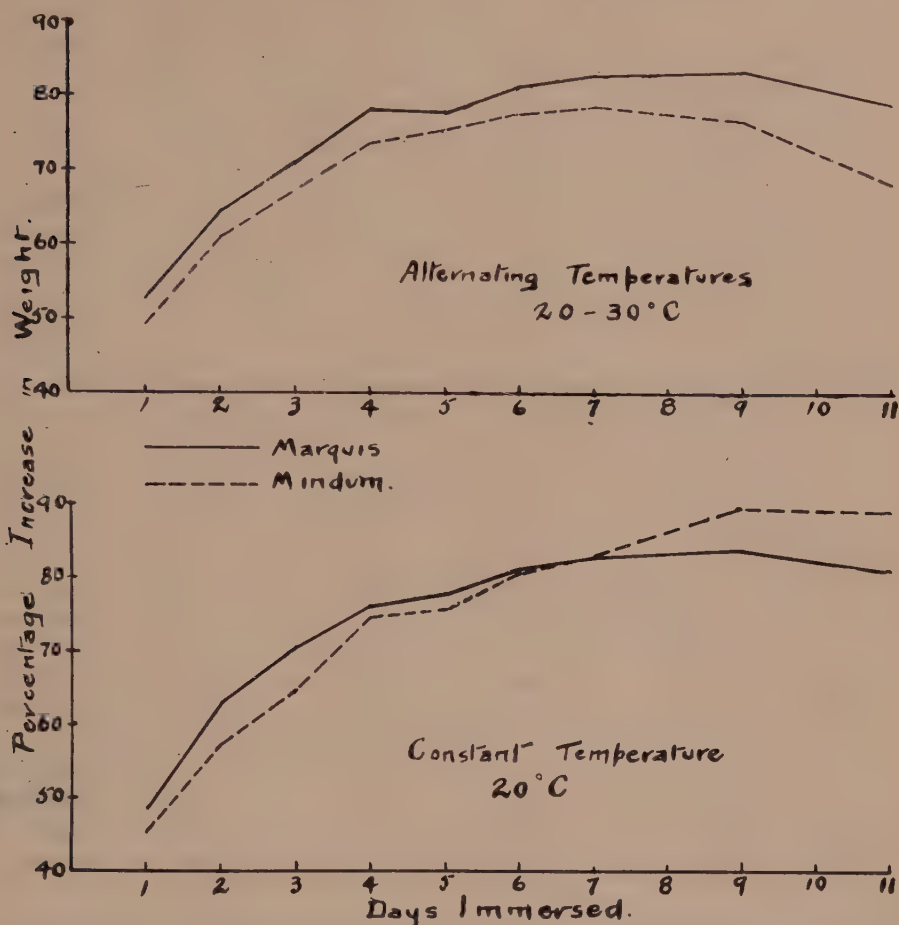


Figure 1. Percentage increase in weight of Marquis and Mindum samples on the basis of air-dry weight. In alternating temperatures, 20°C. maintained for about 18 hours a day, 30°C. for about 6 hours a day.

It is realized that changes in weight, possibly after the first day, are not necessarily due to water-absorption alone but rather to a balance between the weight of water going in and the weight of substances diffusing out. Miss Choate (6) noted chemical changes in germinating Marquis wheat after about ten hours in the germinator.

Under the conditions of the experiments reported in this paper water-absorption is a factor up to about seven days. The entire increase in weight in per cent has been considered as due to water-absorption alone and has been designated percentage water-absorption.

WATER-ABSORPTION AND GERMINATION OF IMMERSSED WHEAT VARIETIES

The immersed seeds were placed in a germinating chamber at a temperature varying from 19 to 30°C., with the exception noted in the data. Weighings were made at times indicated in table 2. A uniform method of drying, as established in the preliminary test, was used. A record of sprouts appearing was made immediately after weighing and before returning

the seeds to the water. Seeds were considered germinated when the coleorhiza emerged through the testa. The time for drying, weighing and counting each sample, during which the seeds were exposed to the air, was about four minutes. Water was changed every twelve hours until the 24-hour intervals were reached, when the water was changed at each weighing.

The total absorption gives a measure of the capacity of the varieties for water-absorption, but the differences observed in total percentage absorption may be due entirely to absorption in the initial period. Some measure of the rate of absorption is necessary. The percentage absorption per unit period in terms of original air-dry weight has been used as the rate of water absorption (21). It is possible that rate might be more properly expressed by the percentage absorption per period in terms of the total weight in per cent at the beginning of each period. In this paper the percentage absorption per period, in terms of original air-dry weight, has been used as a measure of the rate of water entry.

Table 2 gives the total percentage absorption as determined at the end of each period indicated and the percentage absorption for each successive period.

Table 2 shows some differences in total absorption between the varieties in the initial period. This difference in total absorption is rather consistent in the case of Marquis and Mindum. Reward, which starts with a lower initial absorption, is rather markedly higher in the last few periods, while Kubanka exceeds Mindum throughout. Marquis appears to have reached its maximum in these tests at about 144 hours, while the other varieties gain but slightly in the following period. A graph of the total absorption data would be quite similar to the curves in Figure 1. The differences between Marquis and Mindum are not as marked as in the preliminary studies.

Percentage absorption of the comparable samples in table 2, for 4-hour periods, is given in table 3.

As the observations, from the 48-hour to the 168-hour period, were made at 12- and 24-hour intervals, only the percentage absorption for 4-hour periods is given in table 3. It will be noted that in all varieties water entry is very rapid in the first four hours, in the second period rate of absorption is about halved, and for the third period has been nearly halved again, decreasing consistently until the 20-hour period is reached. Some of the samples in the above table were exposed to an increased temperature somewhere in the next two periods and large irregularities are found. For example, Mindum, in the comparison with Marquis, had gained appreciably in water content in the 28-hour period, only to lose some water in the following period. An apparent irregularity in water-absorption, common to all varieties, occurs in the 48-hour period. No explanation can be offered for this marked increase in water-absorption. No increase in temperature was observed, as in the previous instance. All samples at 48 hours show this increase, and as these data are averages of samples tested at three different times, an unobserved increase in temperature in all three tests does not seem possible. In general, however, the percentage absorption in unit time becomes smaller in the successive periods.

TABLE 2. *Total percentage water-absorption of wheat varieties and percentage water-absorption for each successive four hour period.*

Hours Immersion	Marquis (b) Av. 7 samples			Mindum (c) Av. 7 samples			Marquis (d) Av. 5 samples			Reward (e) Av. 5 samples			Mindum (f) Av. 2 samples			Kubanka (g) Av. 2 samples		
	Total % Absorption	% Absorption per period	Total % Absorption	Total % Absorption	% Absorption per period	Total % Absorption	Total % Absorption	% Absorption per period	Total % Absorption	Total % Absorption	% Absorption per period	Total % Absorption	Total % Absorption	% Absorption per period	Total % Absorption	Total % Absorption	% Absorption per period	
4	23.13	23.13	20.24	20.24	20.24	23.39	23.39	23.39	22.45	22.45	22.45	18.41	18.41	18.41	20.35	20.35	20.35	
8	34.52	11.39	30.43	10.19	35.55	12.16	35.55	12.16	34.17	11.72	11.72	30.44	12.03	12.03	34.08	13.73	13.73	
12	41.98	6.96	37.13	6.70	42.04	6.49	42.04	6.49	40.09	5.92	5.92	37.17	6.73	6.73	40.92	6.84	6.84	
16	45.86	4.38	41.05	3.92	46.59	4.55	46.59	4.55	44.48	4.39	4.39	41.63	4.46	4.46	45.50	4.58	4.58	
20	48.71	2.85	44.36	3.31	49.54	2.95	49.54	2.95	47.73	3.25	3.25	44.35	2.92	2.92	49.18	3.68	3.68	
24	51.86	3.15	47.64	3.28	52.08	2.54	52.08	2.54	51.10	3.37	3.37	48.19	3.64	3.64	52.92	3.74	3.74	
28	54.84	2.98	52.06	4.42	55.40	3.32	55.40	3.32	53.70	2.60	2.60	52.41	4.22	4.22	55.49	2.57	2.57	
32	56.07	1.23	51.89	-0.17	56.80	1.40	56.80	1.40	55.18	1.48	1.48	53.42	1.01	1.01	57.78	2.29	2.29	
36	58.04	1.97	54.33	2.44	58.87	2.07	58.87	2.07	57.83	1.73	1.73	55.31	1.89	1.89	59.03	1.25	1.25	
40	59.89	1.85	56.08	1.75	60.59	1.72	60.59	1.72	59.56	1.73	1.73	57.49	2.18	2.18	61.38	2.35	2.35	
44	61.32	1.43	57.65	1.57	61.93	1.34	61.93	1.34	61.04	1.48	1.48	58.89	1.40	1.40	62.37	0.99	0.99	
48	63.97	2.65	59.63	1.98	63.99	2.06	63.99	2.06	63.34	2.30	2.30	61.27	2.38	2.38	65.42	3.05	3.05	
60	66.94	2.97	63.03	3.40	67.28	3.29	67.28	3.29	67.08	3.74	3.74	66.59	5.32	5.32	70.18	4.76	4.76	
72	69.08	2.14	65.00	1.97	69.41	2.13	69.41	2.13	69.42	2.34	2.34	68.42	1.83	1.83	71.69	1.51	1.51	
96	74.12	5.04	71.20	6.20	72.75	3.34	72.75	3.34	74.20	4.78	4.78	75.24	6.82	6.82	78.02	6.33	6.33	
120	76.26	2.14	73.60	2.40	74.33	1.58	74.33	1.58	76.57	2.37	2.37	78.65	3.41	3.41	81.99	3.97	3.97	
144	76.36	0.10	76.267	2.67	74.47	0.14	74.47	0.14	78.05	1.48	1.48	84.34	5.69	5.69	87.02	5.03	5.03	
168	75.45	-0.91	76.86	0.59	73.18	-1.29	73.18	-1.29	78.42	0.37	0.37	85.16	0.82	0.82	87.28	0.26	0.26	

(a) Large discrepancies in this and the following reading are thought to be due to an increase in temperature in the period 24-28 hours. Four samples of Marquis and Mindum with data recorded here were subjected to the increased temperature. Mindum appears to have been most affected.

Samples used in this experiment were:

- (b) 7161, 7175, 7183, 7418, 7429, 7430, 7431
 (c) 7173, 7180, 7192, 7420, 7448, 7449, 7450
 (d) 7161, 7175, 7183, 7418, 7647
 (e) 7169, 7179, 7191, 7419, 7649
 (f) 7173, 7180
 (g) 7174, 7181

TABLE 3. *Percentage water-absorption of wheat varieties and differences for four hour periods.*

	PERIODS											
	4	8	12	16	20	24	28	32	36	40	44	48
Marquis	23.13	11.39	6.96	4.38	2.85	3.15	2.98	1.23	1.97	1.85	1.43	2.65
Mindum	20.24	10.19	6.70	3.92	3.31	3.28	4.42	-0.17	2.44	1.75	1.57	1.98
Difference	2.89	1.20	0.26	0.46	-0.46	-0.13	-1.44	1.40	-0.47	0.10	-0.14	0.67
Marquis	23.39	12.16	6.49	4.55	2.95	2.54	3.32	1.40	2.07	1.72	1.34	2.06
Reward	22.45	11.72	5.92	4.39	3.25	3.37	2.60	1.48	2.65	1.73	1.48	2.30
Difference	0.94	0.44	0.57	0.16	-0.30	-0.83	0.72	-0.08	-0.58	-0.01	-0.14	-0.24
Kubanka	20.35	13.73	6.84	4.58	3.68	3.74	2.57	2.29	1.25	2.35	0.99	3.05
Mindum	18.41	12.03	6.73	4.46	2.92	3.64	4.22	1.01	1.89	2.18	1.40	2.38
Difference	1.94	1.70	0.11	0.12	0.76	0.10	-1.65	1.28	-0.64	0.17	-0.41	0.67

The difference in the rate of absorption between the common wheat variety, Marquis, and the durum variety, Mindum, is appreciable in the first two periods. It is not so marked between the two common varieties, Marquis and Reward, but between Mindum and Kubanka, the durum wheat varieties, it is again rather marked. After the second and third period the difference becomes quite irregular, except in the case of Marquis and Reward. Data in this table and in table 2 show that a higher rate of absorption of Reward evident in the 32-hour period continues consistently until the end of the test. From the 96-hour to the 168-hour period, that is for the last four weighings, the rate of absorption of Mindum was consistently, though irregularly, higher than that of Marquis. This is due to the fact, indicated in the preliminary data, that Marquis does not have as great a water capacity as Mindum, and reaches its maximum in a shorter time. In the comparison of Mindum with Kubanka in later periods than those shown in table 3, there is an irregular tendency for Mindum to exceed Kubanka.

The greatest differences in the three comparisons occur in the first period. The odds that the varieties have a significant statistical difference in rate of water-absorption were determined for the first period by the "Student" method. The approximate odds that the difference between Marquis and Mindum is significant are 163:1, using an "n" of 7; that Marquis exceeds Reward ($n = 5$) odds are 4.35:1; and that Kubanka exceeds Mindum ($n = 2$) the odds are 10.3:1.

Table 4 gives the percentage germination for these varieties at the end of the 168-hour immersion period, and the 6- and 10-day counts of a germination test in blotters at 20°C., following the rules laid down by the Association of Official Seed Analysts of North America (1).

TABLE 4. *Percentage germination of wheat varieties*

	Marquis 7 samples	Mindum 7 samples	Marquis 5 samples	Reward 5 samples	Mindum 2 samples	Kubanka 2 samples
Immersed						
168 hours	94	51	92	97	41	50
6 day count	93	81	92	94	94	84
10 " "	96	84	95	97	99	94

Very marked differences in the germination of durum and common wheats, when totally immersed in water, are evident in this table. In the immersed common wheats the percentage of sprouts appearing at the 168-hour period is about equal to the normal germination in per cent at the 6- and 10-day counts of the regular test. In the durums the percentage germination of the immersed samples falls much below that of the normal test. It is evident that some factor other than the rate of water-absorption is responsible for the difference in germination of the durum varieties under the two conditions. It is not feasible, then, to correlate water-absorption directly with the germination data obtained. It should also be noted that Reward germinates slightly better than Marquis under both conditions and that Kubanka germinates better than Mindum in the immersed tests but less than Mindum in the normal blotter tests. The high germination under normal conditions of the durums in the Mindum and Kubanka data is rather out of the ordinary.

The first sprouts in the common and durum varieties appeared about the same time, usually in the 16-hour period, but in the succeeding periods the sprouts appeared more rapidly in the common varieties. In the Marquis and Reward comparison Reward started a little earlier and in general germinated faster. In general also, more sprouts per period were obtained in Kubanka than in Mindum.

A marked difference in absorption, particularly in the initial period, between Marquis and Mindum is evident in table 2. A very marked difference in germination between these varieties is indicated in table 4. The difference in germination is considered to be due to a factor other than water-absorption (see Discussion, page 385) so a definite conclusion regarding water-absorption and germination cannot be drawn. In the Marquis and Reward data, Marquis absorbed water faster in the early periods than did the Reward, but gave a lower germination under the two conditions, and a slower germination when immersed. Kubanka, with a higher initial rate of absorption, germinated higher and more rapidly than Mindum in the immersed tests, but in the normal test gave a lower germination. There are then no definite indications that the higher initial rate of water-absorption is necessarily associated with a high total germination and a high rate of germination. Further evidence favoring this conclusion is presented in the following experiment.

ABSORPTION AND GERMINATION OF WHEAT HARVESTED AT DIFFERENT DATES AFTER MATURITY

Eight samples of Marquis, (7424 to 7431), harvested at the usual date of cutting with the binder and on subsequent dates, were used for trial. The lots of wheat from which these samples were taken were cut on the days indicated in table 5, and threshed immediately. Moisture determinations were made, the weights per bushel were obtained and the wheat spread out on screen racks to dry. The percentage absorption per unit period was derived as in the previous data, and percentage germination was obtained in the same manner. The percentage germination per unit period represents the sprouts emerging in that period alone. The first date of harvest was August 1, and the absorption and germination tests were made early in the following May. Tables 5 and 6 present the data in part.

TABLE 5. *Percentage absorption per four-hour period at intervals indicated and total percentage absorption at 144th hour* of Marquis † wheat at different dates of harvest.*

Date of Harvest		% Moisture Content		Hours Immersion						Total % Absorption
		At Harvest	At Time of test							144 hrs.
				4	8	12	16	44	48	
August	1	31.8	9.8	27.42	10.21	5.32	2.60	1.42	1.46	77.64
"	3	33.6	9.9	25.61	9.62	8.40	2.01	1.50	1.73	76.12
"	5	24.0	9.9	22.53	10.55	7.48	4.20	1.83	2.42	81.67
"	7	18.0	9.9	22.38	9.29	9.15	3.91	1.97	3.26	83.07
"	9	14.0	10.0	23.20	10.54	7.96	3.82	1.89	2.76	82.00
"	11	13.5	10.2	23.50	9.54	7.76	3.77	1.82	3.05	80.69
"	15	10.3	22.48	10.92	6.49	4.37	1.04	3.16	76.28
"	19	10.4	22.76	10.77	7.10	4.13	1.84	3.31	76.84

*The 144th was used because in some instances there was a decrease in the final period.

†Marquis was considered ready for the binder on July 28.

The percentage absorption per period of the samples shown in table 5 differs markedly only in the initial period. As in the previous test, this soon decreases and becomes fairly consistent for all dates of harvest. In the 4-hour periods the minimum absorption per period is reached at 44 hours and an unexplained rise occurs again in the following period. The inconsistency of the percentage moisture content of the wheat harvested on August 3 is due to a rain of 1.4 inches which fell between this and the previous date of harvest. The data indicate that the early cut wheat absorbs water more rapidly in the initial period than the wheat harvested later.

TABLE 6. *Percentage germination per period and total percentage germination at 144th hour of Marquis at different dates of harvest.*

Date Harvested	Hours Immersion										Total % germ 144 hrs.
	12	16	20	24	28	32	36	40	44	48	
August 1	—	—	—	2	1	5	—	11	6	15	49
" 3	—	—	—	—	—	2	2	2	3	8	45
" 5	—	—	—	1	1	2	9	20	6	25	83
" 7	—	—	—	4	5	7	15	19	10	23	92
" 9	—	—	1	4	9	1	11	16	13	29	97
" 11	—	—	—	8	19	7	5	28	6	17	98
" 15	1	0	1	5	20	4	3	29	5	17	95
" 19	—	2	2	14	15	2	11	26	9	11	96

In table 6, wheat harvested on August 1 first sprouted in the 24-hour interval, while in the wheat harvested on August 19, sprouts appeared in the 16-hour interval. A regular emergence, in the intervening period of immersion, of sprouts in the samples harvested between these dates, is not obtained, the sprouts emerging irregularly. The data indicate, however, that Marquis harvested at the later dates, germinates more rapidly than that harvested earlier. The later harvested wheat also gives a greater total germination.

These data resemble data presented by Dungan (9) who, using corn in the "milk-, dent- and mature-stages", found marked differences in water-absorption, the immature stages having an increased rate of absorption. He attributed these differences to different proportions of soft starch in the three stages of maturity. Dungan also found that the "milk-stage" corn began germinating earlier than the dent stage, which in turn was earlier than the mature stage. The total germination was in the inverse order to earliness of germination.

Agronomically, maturity is considered as that point where translocation of food material into the kernel ceases. Olson (22) observed that wheat does not fill after the moisture content has dropped to 40 per cent. Kiesselbach (15) made a similar observation. While the samples used here may not represent different stages of maturity, it is believed that the changes in the state of the endosperm material, such as Dungan suggested for his corn, are responsible for the differences in rate of water-absorption.

The endosperm may be likened to a gel. With comparatively slow drying of the seed in racks, water would be removed more uniformly from the kernel than in the more rapid drying of grain on the mature plant. In a gel, rapid drying forms a tougher and less water-soluble surface than

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The available data giving the percentage water-absorption for 4-hour periods of Marquis and Mindum show the rate of water-absorption of immersed seeds in the first two periods to be practically double the rate of seeds germinated in blotters. In succeeding periods the differences in rate of absorption, though smaller, are fairly consistent.

It is of interest also to note the sprouts which appeared after 36 hours under the two treatments in the samples used in table 7. These data appear in table 8.

TABLE 8. Percentage germination of Marquis and Mindum seeds immersed and in blotters at 36 hours.

	Immersed	In Blotters
Marquis	48	64
Mindum	17	21

In table 8 it will be noted that Marquis when immersed gave a slightly higher percentage germination than when germinated between blotters. With Mindum, a slightly higher germination was obtained between blotters.

Despite the large differences in absorption in the initial periods, shown in table 7 under the two methods of treatment only a small difference is obtained in germination. This substantiates the conclusion previously reached, that a higher initial rate of absorption is not necessarily associated with higher rate of germination. It appears also, that the marked difference in germination between the immersed samples of Marquis and Mindum in table 4 was not extraordinary, but was to be found under ordinary germination procedure. It seems then that the delay in germination of the Mindum is almost as great a factor in seeds germinated in blotters as when the seed was completely immersed.

The total percentage absorption in blotters and the percentage absorption for one-hour periods at three temperatures are given in table 9. As water was considered necessary to maintain normal germinating conditions in the 35°C. lot after 10 hours, only data up to that point are presented.

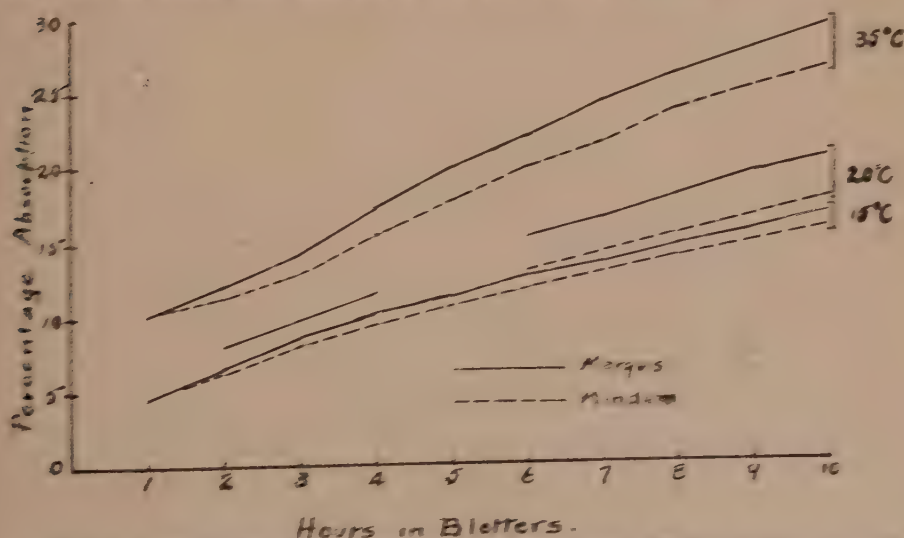


FIGURE 1. Percentage water-absorption of Marquis and Mindum samples in moist blotters at 35, 20 and 15°C. Data from table 9.

In this figure it will be observed that at any of the periods indicated the higher temperature has given a marked increase in percentage of water absorption. The absorption of Mindum at 20°C. was about equal to that of Marquis at 15°C. in the second period and slightly less than that of Marquis at 15°C. in the third and fourth period. To avoid a confusion of lines the percentage absorption of the Mindum at these periods has not been shown in the graph.

The effect of the three temperatures on the percentage absorption for one-hour periods is given in Figure 3.

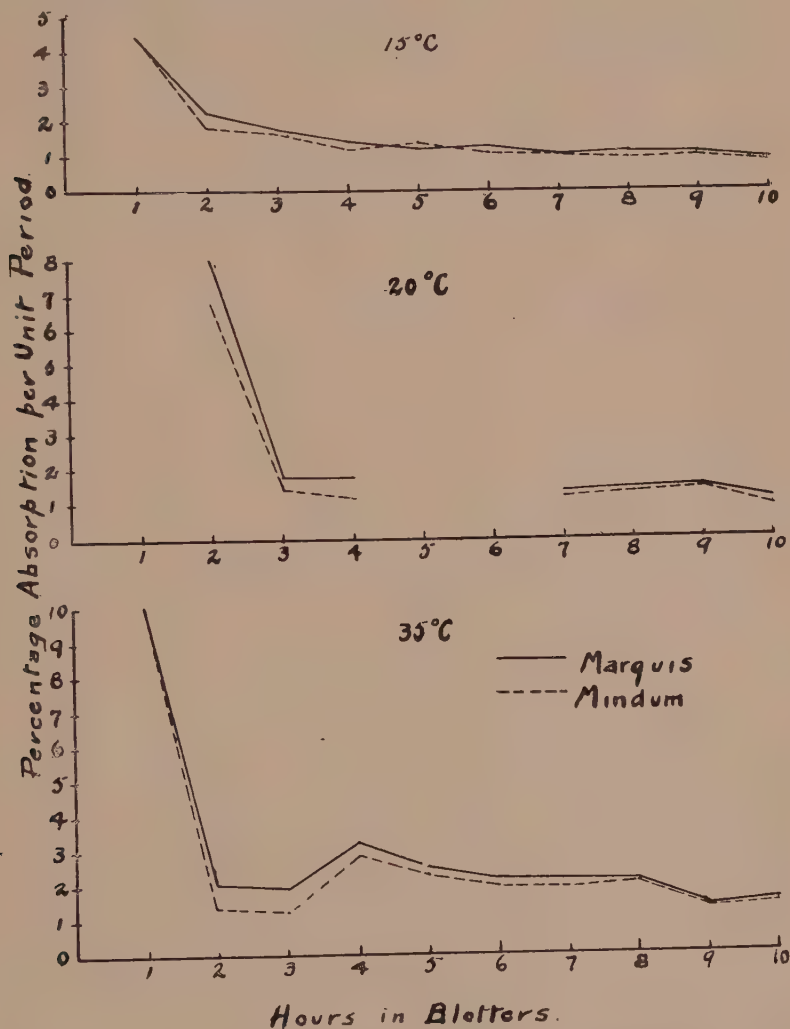


Figure 3. Percentage water-absorption of Marquis and Mindum samples for successive one-hour periods. Samples in moist blotters at 35, 20 and 15°C. Data from table 9.

In Figure 3 at 35°C. a marked second maximum in the percentage absorption per unit period is to be noted at 4 hours, and at 15°C. a slight rise is observed in Mindum at 5 hours and in Marquis in the following hour. Ohga (21) noted a double maximum in the rate of water absorption

of Indian Lotus seeds, but did not give an explanation for it. It may also be observed that the differences in percentage absorption per unit period between Marquis and Mindum increase in general with a rise in temperature.

Mindum exceeds Marquis slightly in percentage absorption for the first hour. This is thought to indicate that during this period at least part of the increase in weight is a result of water adsorbed by the seed coat rather than a penetration through it. If such is the case, the effect of the less permeable nature of the Mindum seed coat would not be evident. In the succeeding periods, with two exceptions in the 15°C. test, the rate of absorption of Marquis is greater than that of Mindum. The odds that the rate of absorption per hour of Marquis is significantly greater than that of Mindum have been worked out for the individual periods at each of the three temperatures. The number of times that these odds fall below certain arbitrary limits is given in table 10. Averages of the actual odds for all periods at each temperature are also given. As complete data were not obtained at 20°C., only the odds for seven periods are indicated.

TABLE 10. *Number of periods where odds, that Marquis and Mindum differ significantly in rate of water absorption per hour, fall below the arbitrary odds indicated.**

	Odds Less Than									Average odds
	5	15	30	60	90	120	150	180	210	
At 35° C.	4	1	1	2				1	1	48:1
At 20° C.	2	2		2	1					25:1
At 15° C.	5	2	1			1		1		30:1

*In these calculations $n = 4$.

GERMINATION IN FIELD TEST

It was considered desirable to determine whether the differences in germination in the laboratory tests were to be found under actual field conditions. Due to the courtesy of the Dominion Rust Research Laboratory, Winnipeg, Man., duplicate lots consisting of 100 seeds of each variety were planted in two series. Rows were marked out one foot apart and the drills opened with a Planet Junior (plow attachment). The seed was planted by hand at the rate of 25 seeds in a 5-foot row, and covered to a depth of 2½ to 3 inches with a hoe. The grain was planted on June 3, as soon as possible after a heavy rain. There was little or no rain between the time of planting and of counting. Counts, made 12 and 18 days after planting, are shown in table 11.

TABLE 11. *Percentage germination in field test of wheat varieties. (See Table 4).*

Days after Planting	Percentage Germination					
	Marquis 7 samples	Mindum 7 samples	Marquis 5 samples	Reward 5 samples	Mindum 2 samples	Kubanka 2 samples
12	18	10	16	16	12	13
18	19	11	16	17	12	14

Although this field test does not compare at all favorably with the laboratory tests, it is seen that about the same relation between the commons and durum was obtained. The lack of rain following planting is no doubt responsible for the low germination obtained here. It is possible, too, that the drills were opened too far ahead of the seeding, there being some 74 samples, other than those reported here, sown at the same time.

DIFFERENCES IN SUSCEPTIBILITY TO MOLD

In seed laboratory work it is often observed that durum wheats appear more susceptible to mold than do common wheats. Seven Marquis and seven Mindum samples were put in for a normal germination test and counts were made on the 6th day of kernels on which mold had developed. The average number of molded kernels found on 7 samples of each of the two species were: Marquis 2.6 per cent, Mindum 7.1 per cent. In three cases the mold count was no greater in Mindum than in Marquis, but the more marked differences shown in the averages correspond somewhat to the differences found in normal germination procedure.

Species of *Rhizopus*, *Fusarium*, *Penicillium* and *Helminthosporium* were found and identified by Helen Hart, Division of Plant Pathology. The *Rhizopus* species was the most common, appearing in all counts with the other species appearing much less frequently, the frequency being in the order given.

DISCUSSION

Several investigators (7, 19, 31) have found that seeds of many common crops do not germinate under water. A. Kraus (16), according to Morinaga (19), found that wheat, when grown in tap water, pushed hypocotyls out of the testas and made no further growth. Germination has been considered by these authors as that point where healthy development of radicle and plumule is evident. This is the commonly accepted interpretation. Here, because little or no further development took place in completely immersed seeds, they have been considered germinated when the radicle sheathed in the coleorhiza burst through the testa. This is the sense in which de Candolle (5) uses the word. He considers further development as a period of vegetation.

The large differences in germination, between completely immersed samples of durum and common wheat, have been attributed to some factor other than the rate of water absorption. On immersing seeds in water Coupin (7) found two of the injurious effects on subsequent growth to be loss of soluble food material and lack of oxygen.

Kidd and West (14) considered that an accumulation of carbon dioxide and a lack of oxygen, rather than the loss of soluble food materials, are chiefly responsible for the injurious effects. Kidd (13), in experiments with white mustard seed, believed that the accumulation of carbon dioxide lowers the permeability of the semi-permeable membrane to gases, hindering the elimination of carbon dioxide and the absorption of oxygen. As oxygen is one of the prerequisites of germination a lack of oxygen would result in delayed germination. It has been shown here that differences in the percentage water-absorption for unit periods are not consistently associated with rate

of germination. The differences in permeability to water, of the seed coats and of the semipermeable membranes of the seed and the individual cells then do not appear to be responsible for the differences found in germination. It is suggested that differences in permeability to carbon dioxide and oxygen may be responsible for the differences in germination.

The differences in germination between Marquis and Mindum have been found to be almost as great when the samples were germinated in blotters as when they were completely immersed. The blotter tests were continued, after weighing had ceased, and contents were made at 6 and 10 days. Marquis, after 10 days in blotters at 20°C, germinated 92 per cent and Mindum 88 per cent. This would indicate that in neither the immersed samples nor in those in blotters was there the marked difference in the live seeds of the two species, that germination data at the end of 7 days immersion and after 36 hours in blotters might appear to show. The differences between the samples of the two species in rate of absorption cannot then be ascribed to variations in power of absorption of live and dead seeds.

According to Munn (20) the amount of fungous infestation of seed, as shown in germination testing, depends upon the conditions of harvesting, character of the seed coat or covering, whether rough or smooth, and the vitality of the seed. Hurd (12) showed that an unbroken seed coat affords absolute protection against species of *Penicillium* and *Rhizopus* in damp soil or blotters, although infection had been obtained by retarding germination. Injured seed coats were susceptible, but the location of the break was most important. A break over the embryo left the seed practically immune, while a break over the endosperm gave a 100 per cent fatal infection.

The breaks in seed coats are considered due to mechanical injury at threshing time, or in subsequent handling, as in seed cleaning. It is possible that, on account of the more brittle nature of the durum seed coat, it is easier to injure than that of the common. Wilson (33) found little variation in susceptibility to mold between samples of wheat representing the commercial classes of common wheat, Hard Red Spring, Hard Red Winter and Soft Red Winter.

Hurd found (see above) that infection was obtained by retarding germination. Delayed germination is common in Mindum as has been indicated here.

The differences of common and durum wheats in susceptibility to fungi, may be due to differences in susceptibility at the time of harvest, to a more frequent occurrence of minute breaks in the seed coat of the durums making later infection possible or to the differences in rate of germination. It appears probable that the delayed germination in the Mindum is a major factor in its susceptibility to molds. It is obvious that the variations in susceptibility are responsible in part for differences in germination of the common and durum wheat.

SUMMARY

This paper deals with differences in water-absorption and germination of varieties of *T. vulgare* and *T. durum*. The varieties used were Marquis and Reward for the common, and Mindum and Kubanka for the durum wheats.

The greatest differences, in rate of water-absorption of seeds completely immersed in water, were found in the initial 4-hour period. The approximate odds that the varieties differ significantly in water-absorption in the first period are: 163:1 that Marquis exceeds Mindum; 4.35:1 that Marquis exceeds Reward; and 10.3:1 that Kubanka exceeds Mindum.

It was impossible to correlate water-absorption directly with germination because a second factor, possibly lack of interchange of gases, interfered with the germination of the durum wheats.

In Marquis wheat harvested at various dates after maturity, the earlier harvested samples absorbed water more rapidly than those harvested at later dates. In general the rate of germination was found to be in a reverse order.

The percentage absorption per period, for the first 3 periods of 4 hours each, was much higher in the totally immersed samples than in samples between moist blotters. Greater differences in the rates of water-absorption of Marquis and Mindum were found in the immersed samples than in those in blotters. There was little difference in germination between the immersed and blotter samples at the end of 36 hours. *

Differences in percentage absorption of Marquis and Mindum germinated in blotters, for one-hour periods, were studied. Except in the initial period, where little difference was obtained, Marquis in general absorbed water more rapidly than did Mindum.

The effect of temperature on absorption of water was noted. The difference between Marquis and Mindum in percentage absorption per unit period was found to increase in general with a rise in temperature.

It was concluded that a higher initial rate of absorption was not necessarily associated with a higher rate of germination, and that differences in water-absorption of the wheat varieties used in this test are not responsible for the differences in their germination.

It was suggested that differences in permeability to gases rather than to water may account for the differences in germination between *T. vulgare* and *T. durum*.

In field tests, as under laboratory conditions, the durums had a lower germination than the common wheats.

Mindum wheat was found to be more susceptible to molds than was Marquis. Delayed germination in the Mindum was believed to be a major factor in the susceptibility of the Mindum to mold.

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II. THE INHERITANCE OF RESISTANCE TO *PUCCINIA GRAMINIS TRITICI* IN CROSSES BETWEEN VARIETIES OF *TRITICUM VULGARE* *

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INTRODUCTION

The discovery of the existence of numerous physiologic forms of the organism *Puccinia graminis tritici* Erikss. and Henn. by Stakman and his co-workers (14, 15, 16) was one of very great importance to the wheat breeder. In breeding for resistance to stem rust the causal organism could no longer be regarded as a single entity. The problem was immediately concerned with many morphologically similar organisms fundamentally different in pathogenic capabilities. The situation was further complicated by the discovery of heterothallism in the stem rust organism by J. H. Craigie (4). Through this discovery the possibility of the multiplication of physiologic forms through natural hybridization was indicated. While these facts are of great biological interest, in the light of recently obtained results on the breeding behaviour of rust resistance, they are less alarming to the plant breeder than they appeared at first.

An extensive review of early work on the inheritance of resistance to stem rust of wheat is given by Aamodt (2). One of the most valuable contributions was made by Aamodt (1). In this study he showed that the inheritance of immunity to several physiologic forms was governed by a single pair of factors. Since that time at least three similar "groups" have been identified (Goulden *et al* (7), Harrington (8) and Neatby (unpublished data)). It is possible, therefore, that from a genetic point of view the sixty-odd physiologic forms hitherto identified may be regarded as not more than four or five entities.

Of even greater significance from the point of view of breeding for resistance to stem rust is the development of resistance in certain varieties of wheat with the advancing maturity of the plant. The physiologic forms of *P. graminis tritici* have all been classified according to their ability, or inability, to parasitize seedlings of certain wheat varieties. The identification of physiologic forms thus classified would be difficult, sometimes impossible, if inoculations were made on wheat plants after the latter had headed. For example, forms 36 and 52 differ chiefly in their reaction on Vernal emmer. Vernal is very susceptible in the seedling stage to form 52, but under field conditions when this and other forms which attack it in the seedling stage have been introduced, Vernal has always been highly resistant. Furthermore, varieties such as Acme and Velvet Don may be susceptible to many forms in the seedling stage, and highly resistant in the field. It is always possible that there may ap-

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pear physiologic forms capable of attacking three varieties in the field; but evidence presented in this and other papers (3, 7) emphasizes the improbability of such an occurrence and the consequent importance of this mature plant type of resistance in the breeding programme.

Recent genetical investigations have revealed the fact that a high degree of mature plant resistance may be inherited in a very simple manner. This has been emphasized by Goulden *et al* (6, 7) and by Clark and Ausemus (3). The latter investigators consider the variety Hope immune to stem rust. In the cross Marquis \times Hope they conclude that two genetic factors operate in the inheritance of immunity. It is probable that the immunity of Hope under their conditions is partly due to the inadequacy of the epidemic. Under conditions prevailing in the Winnipeg nursery, Hope usually carries an infection of from five to ten per cent (see Figure 1.).



Figure 1. Illustrating the field reaction of Hope wheat to stem rust. Left, lower leaf sheaths; right, upper leaf sheaths.

At University Farm, Minnesota, Dr. H. K. Hayes and others (9, 10, 11) have attempted to develop wheat varieties resistant in the seedling stage to all known forms of wheat stem rust. These efforts have been conspicuously successful. Several strains of *T. vulgare* type have been developed which are immune or highly resistant to many forms, and show some resistance to all others to which they have been tested. These strains are highly resistant under field conditions.

During the past three years the inheritance of resistance to wheat stem rust in the field has been studied in various crosses at the Dominion Rust Research Laboratory. The results of these investigations are presented in the following paragraphs.

FIELD METHODS

All the material used in this study was grown in the hybrid nursery under severe epidemic conditions. In the year 1927 the nursery was located at Morden, Manitoba; in 1928 and 1929 the material was all grown at Winnipeg. The seed was planted in five-foot rows, approximately 25 seeds being planted in each row. In F_3 studies three rows of each line were planted, except in a few cases when the supply of seed was inadequate. In F_2 generations the progeny of each F_1 plant was grown in a separate plot, so that had any selfing occurred at the time the cross was made, the resulting lines could be discarded. Three-row plots of the parent varieties concerned were planted at frequent intervals for purposes of comparison.

In order to facilitate the spread of the rust epidemic, one row of Garnet wheat was drilled along both sides of each series of five-foot rows. About the last week in June heavily infected plants were taken from the greenhouse and planted in the border rows of Garnet. These rusted plants were at the same stage of maturity as those in the nursery. All available physiologic forms were introduced into the nursery in this manner. In no case has this method failed to produce a very severe epidemic.

A discussion of the results obtained in eleven different crosses is contained in the following section. Since the time and space requirements for studies conducted in the F_3 generation are very considerable, most of the data presented are derived from F_2 material. However, three crosses have been studied in both the F_2 and F_3 generations, and the results are presented and discussed in detail.

EXPERIMENTAL RESULTS

Marquis \times *H-44-24*.

The variety designated H-44-24 was selected from a cross between Marquis and Yaroslav emmer by E. S. McFadden (13). It is highly resistant to stem rust, and even under severe epidemic conditions only five to ten per cent infection occurs. This infection is almost invariably confined to the lower leaf sheaths.

In a cross between H-44-24 and Marquis, of 1280 F_2 plants 966 were resistant, and 314 were susceptible. The deviation from a 3:1 ratio is 6 ± 10.3 . While resistance is not completely dominant in this cross, an accurate distinction between homozygous and heterozygous resistant plants cannot always be made. Of the 1280 F_2 plants 1204 gave a sufficient quantity of seed for F_3 plantings. The shortage of seed of 76 plants was not a result of rust infection, but of breakages in handling; therefore, the F_3 sample was selected strictly at random. The breeding behaviour of the F_2 plants is given in table 1. These figures agree fairly well with the single factor explanation offered. Of 281 susceptible F_2 plants only seven failed to breed true. These may easily have resulted from outcrossing in the F_1 generation with varieties having factors for susceptibility dominant to the H-44-24 factor for resistance. A further discussion of the question of natural crossing is given below. The fact that eight resistant F_2 plants proved susceptible in the F_3 is not easy to explain. Occasionally plants of susceptible varieties have been observed to remain free from rust as a result of the attacks of foot-rotting

TABLE 1. *The breeding behaviour of F_2 plants in the cross H-44-24 \times Marquis.*

		F ₃ reactions.			
		R	Seg.	S	
F ₂ reactions	R	224	691	8	923
	S	...	7	274	281
		224	698	282	1204

*The following symbols are used throughout, R = resistant, SR = semi-resistant, Seg. = segregating, MS = moderately susceptible, and S = susceptible.

organisms. The absence of rust on these F_2 plants may, therefore, have been a result of the attacks of other pathogens. It is also possible that their position in the resistant F_2 class is a result of clerical errors. In any case the number is not sufficiently great to indicate the operation of additional genetic factors.

Table 2 contains the observed and calculated numbers based on a 1:2:1 ratio. The agreement is far from satisfactory, largely on account of the excess of segregating and corresponding deficiency of resistant lines. However, if the resistant and segregating classes are combined, the deviation from a 3:1 ratio is only 19 ± 10.1 . As an additional check on the segregation, 64 segregating F_3 lines were studied individually, and the ratio of resistant to susceptible plants determined. The χ^2 test as described by Kirk and Immer (12) was applied. The ratio of the deviation to its standard deviation was found equal to 5.57. This also implies a significant departure from a 3:1 ratio.

TABLE 2. *Comparison between the observed and expected numbers in each infection class in the F_3 generation of the cross H-44-24 \times Marquis on the basis of a 1:2:1 ratio.*

	Observed	Calculated	O - C	$\frac{(O - C)^2}{C}$
R	224	301	77	19.70
Seg.	698	602	96	15.31
S	282	301	19	1.20
	1204			$\chi^2 = 36.21$

From extensive observations of characters other than field rust reaction, the authors are convinced that natural crossing is very frequent in this material. For example, the variety Garnet has a very characteristic rust reaction in the greenhouse. The pustules are surrounded by a deep red pigmentation, which is entirely absent from pustules on Marquis or H-44-24. In Marquis \times H-44-24 F_3 lines otherwise constant for resistance to a certain physiologic form in the greenhouse, one or two susceptible seedlings with the red coloration of Garnet have frequently been observed. Furthermore, in F_3 and F_4 lines otherwise constant for the fully awned condition, one or two plants with intermediate awns are often present. Also in lines constant for resistance to stem rust in the field, the occurrence of one or two plants susceptible to rust is not infrequent.

In view of these facts a deviation from a 1:2:1 ratio, as shown in table 2, is to be expected. The proportion of susceptible F_3 lines would not be affected by natural crossing in F_2 for the following reasons: (1) Since the H-44-24 resistance is dominant to the Marquis susceptibility, lines having 50 to 60 susceptible plants, and from 1 to 3 resistant plants were placed in the susceptible class. (2) Natural crossing of susceptible F_2 plants with plants in the Garnet border rows would certainly not be detected by the F_3 rust reaction. However, the case of resistant F_2 plants is quite different. It will be shown later that the susceptibility of Reward is dominant to the H-44-24 resistance. If the Garnet susceptibility is also dominant, which is not improbable, natural crossing of resistant F_2 plants with plants in the Garnet border rows would readily explain the observed deviation in the F_3 ratio. The maximum number of susceptible plants present in a line that could be due to natural crossing could not be determined. For this reason the basis of distinction was necessarily arbitrary. When more than two susceptible plants were present in a line, the line was placed in the segregating class. There is little doubt that in many cases more than two susceptible plants appeared in an otherwise resistant line as a result of natural crossing with plants in the border rows. This would readily explain the deficiency of homozygous resistant lines, and also the aberrant ratios observed in individual segregating lines, several of which had a very low proportion of susceptible plants. It appears, therefore, that in order to obtain accurate results in studies of this nature, protection of F_2 plants from foreign pollen is necessary.

In 1928 a small random sample of F_3 lines of the same cross was classified for field rust reaction. Of 270 lines 60 were resistant, 135 segregating, and 75 were susceptible. When these numbers are fitted to a 1:2:1 ratio, a P value of .45 is obtained. In the light of these results there seems little doubt that a single main factor governs the field resistance in this cross. The better fit obtained in 1928 may well be a result of a lower rate of natural crossing in 1927, due to seasonal differences, or possibly due to the Garnet border rows having passed the flowering period before the hybrid plants were in flower.

H-44-24 \times *Reward*.

When H-44-24 is crossed with Reward, the segregation in F_2 is quite different from the preceding. The latter variety was selected from a cross between Marquis and Prelude at the Central Experimental Farm, Ottawa.

In 1928 (see table 7) of 1179 F_2 plants, 264 were resistant. This gives a ratio of about 1:3.5, and suggests a single factor difference with susceptibility dominant. However, the breeding behaviour of these plants, as shown in table 3, clearly indicates the operation of two factors. Segregating F_3 lines were of two types: one in which resistant plants predominated, and another in which there was an excess of susceptible plants. These are designated R:S and S:R respectively. This behaviour suggests the operation of an inhibitor to the factor for resistance possessed by H-44-24. The calculated numbers based on this assumption are compared with the actual numbers in table 4. The fit is unsatisfactory, there being a deficiency in the susceptible class, and an excess in the resistant class. The deficiency of susceptible lines may be partly due to natural crossing since a susceptible F_2 plant

TABLE 3. *The breeding behaviour of F_2 plants in the cross H-44-24 \times Reward.*

		F ₃ reactions				
		R	R:S	S:R	S	
F ₂ reactions	R	90	162	5	2	259
	S	1	2	476	387	866
		91	164	481	389	

heterozygous for, or lacking, the inhibiting factor would produce some resistant plants in its progeny, if crossing with resistant F_2 plants had taken place. However, the excess of homozygous resistant F_3 lines can certainly not be explained in this way.

TABLE 4. *Comparison between the observed and calculated numbers in each infection class in the F_3 generation of the cross H-44-24 \times Reward, based on the theory of independent assortment of the two factors concerned.*

	Observed	Calculated (1:2:6:7)	O - C	$(O - C)^2$ C
R	91	70.3	20.7	6.10
R:S	164	140.6	23.4	3.89
S:R	481	421.8	59.2	8.31
S	389	492.1	103.1	21.60
	1125			$\chi^2 = 39.90$

$P = \text{very small}$

If linkage between the resistance factor and the allelomorph of the inhibitor is assumed, a somewhat better fit is obtained. If the linkage value is calculated from the proportion of homozygous resistant lines, the cross-over percentage is found to be 44 per cent. The actual figures are compared with those calculated on this basis in table 5. This is a much closer fit than that resulting from the assumption of independent assortment of the factors concerned; but it is still far from satisfactory. In this case the deviation of actual from calculated numbers is largely due to the excess of the S:R class, and the deficiency of homozygous susceptible lines. The dominance of susceptibility in F_2 and the two distinct types of segregation within F_3 lines affords strong evidence of the operation of an inhibiting factor.

TABLE 5. *Comparison between the observed and calculated numbers in each infection class in the F_3 generation of the cross H-44-24 \times Reward, based on the theory of linkage between the two factors concerned.*

	Observed	Calculated	O - C	$(O - C)^2$ C
R	91	91.01	.01	.00
R:S	164	137.92	26.08	4.93
S:R	481	424.58	56.42	7.50
S	389	471.49	82.49	14.43
	1125			$\chi^2 = 26.86$

$P = \text{very small}$

The above explanation of a loose linkage between the factor for resistance with the allelomorph of the inhibitor is, therefore, offered tentatively; confirmation or contradiction must await further investigation.

Marquillo × *H-44-24*.

In 1928 the field reaction of 1239 F_3 lines of the cross *Marquillo* × *H-44-24* was determined. The F_2 plants from which these lines were grown were selected at random from a large F_2 population. *Marquillo* shows quite a high degree of resistance under severe epidemic conditions. While the variety *H-44-24* is more highly resistant as a rule, it was not possible to differentiate clearly between the two types of resistance in the F_3 generation. Hence all lines showing resistance equal to that of *Marquillo* were placed in the R class. The resistant and susceptible classes were fairly distinct,

TABLE 6. *Comparison between the observed and calculated frequencies in each infection class in the F_3 generation of the cross *Marquillo* × *H-44-24*, on the basis of a three factor difference.*

	Observed	Calculated	O - C	$\frac{(O - C)^2}{C}$
R	354	367.84	13.84	.52
SR	775	735.68	39.32	2.10
MS				
Seg.	110	135.52	25.52	4.80
S				
	1239			$\chi^2 = 7.42$
		$P = .0252$		

but in the other groups the classification was often doubtful. Varying degrees of resistance rendered the distinction between moderately susceptible, semi-resistant, and segregating lines difficult. The three classes are, therefore, grouped together. The observed and calculated numbers are given in table 6. These figures are based on the assumption that *Marquillo* carries two recessive complementary factors for resistance, and *H-44-24* one dominant factor. The value of .025 for P implies a rather poor fit. The probability that this disagreement is a result of more than two factors being concerned in the *Marquillo* resistance, is strengthened by the ratio obtained in an F_2 generation grown in the same nursery. The figures are recorded in table 7. Of a total of 427 plants only 51 were susceptible, whereas according to the hypothesis outlined above, 98 susceptible plants would be expected. It is probable therefore, that the inheritance of field resistance in this cross is governed by more than three factors.

Double Cross × *H-44-24*.

The variety *Double Cross* was developed by Dr. H. K. Hayes and his co-workers at the University of Minnesota. It was derived from the cross (*Marquis-Iumillo*) × (*Marquis-Kanred*). The field rust reaction of this variety is similar to that of *Marquillo*, and it inherits from *Kanred* immunity to a large group of physiologic forms. The ratio obtained in the F_2 generation of this cross is given in table 7. If two complementary recessive factors for resistance, in addition to the *H-44-24* factor, are assumed to operate, 363 susceptible plants are expected. Since 339 were actually obtained the agreement is much closer than in the case of *Marquillo* × *H-44-24*. It is

probable, therefore, that Marquillo possesses one or two minor factors for field resistance in addition to those concerned in the Double Cross resistance. The reactions of the parents and hybrid classes are illustrated in Figure 2. *H-44-24* \times (*Marquis-Kanred* B_{2-5})

Ratios obtained in the F_2 generation of several additional crosses are given in table 7. The major factors concerned in rust resistance in these crosses are derived from two sources: Yaroslav emmer (the emmer parent of *H-44-24* and *Hope*), and Iumillo (the durum parent of Marquillo). The



Figure 2. Field reactions in the cross Double Cross \times *H-44-24*. Left to right, Double Cross, S, SR, R, *H-44-24*.

crosses are arranged in the table in the approximate order of the complexity of the inheritance of resistance to rust.

Apparently *H-44-24* differs from *Marquis-Kanred* B_{2-5} by one main factor for resistance. When the observed frequencies are fitted to frequencies based on a 1:2:1 ratio, $\chi^2 = 6.26$ and $P = .045$ *Marquis* \times *Kanred* B_{2-5} shows, as a rule, very little resistance under field conditions prevailing in the Winnipeg nursery. In this cross the SR class was distinctly intermediate, but somewhat variable. Since the position of some plants was doubtful, the departure of observed frequencies from a 1:2:1 ratio is probably due to errors in classification.

Marquis \times *Hope*

The origin of the variety *Hope* is similar to that of *H-44-24*; it was also selected from a cross between Yaroslav emmer and *Marquis* by E. S. McFadden (13). Like *H-44-24* it is highly resistant to stem rust in the field. Infection, when it occurs, is always light, and practically limited to the leaf sheaths (see Fig. 1). Apparently, however, its genetic constitution as far as rust resistance is concerned is quite different from that of *H-44-24*. The rust reactions of the parent varieties and F_2 hybrids of the cross *Marquis* \times *Hope* are illustrated in Figure 3. From the ratio given in table 7, it

TABLE 7. *Frequencies in the various rust infection classes of the F₂ generations of several different crosses.*

Cross	Year	R	SR	MS	S	Probable number of factors concerned
Marquis × H-44-24	1928	966			314	1
H-44-24 × (Marquis-Kanred B ₂ -5)	1929	182	416		233	1
H-44-24 × Reward	1928	264			915	2
Marquis × Hope	1929	186	661		502	2
Webster × H-44-24	1929	112	80	203	270	2
Hope × Reward	1929	111	232		1181	3
Double Cross × H-44-24	1929	689	519		339	3
Marquillo × H-44-24	1928	229	147		51	3 +
Marquillo × (Marquis-Kanred B ₂ -5)	1927	4	33		775	3 +
“ “ “ “ “ “	1928	1	18	109	857	3 +
Marquillo × Reward	1927	1	90		1507	many
Garnet × Marquillo	1927	1	81		4929	many

appears that the behaviour in this cross is quite different from that in the cross between H-44-24 and Marquis. Dominance is less complete (see Figure 3.) and there are nearly three susceptible plants for one that is resistant. These figures certainly indicate the operation of two or more

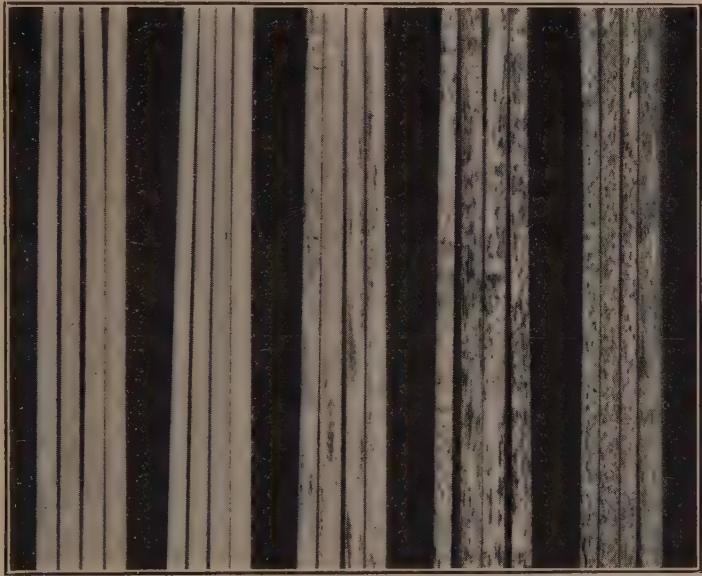


Figure 3. Field reactions in the cross Marquis × Hope. Left to right; Hope, R, SR, S, Marquis.

factors. If two complementary factors for resistance were concerned, one of which when homozygous produces partial resistance, a ratio of 843 resistant and semi-resistant to 506 susceptible plants would be expected. The deviation of the observed ratio from this is only 4 ± 12.0 . If the two factors were strictly complementary 590 susceptible plants would be expected. While this gives a deviation of 88 ± 12.3 , yet the results obtained in the cross about to be discussed lend weight to an explanation based on a strictly complementary relationship between two factors. Since dominance is incomplete, separation into two distinct classes, one resistant and one susceptible, is much more difficult than in the case of Marquis × H-44-24. Some errors in classification are, therefore, unavoidable.

Hope × Reward

In an earlier section it was shown that when H-44-24 was crossed with Marquis the results were quite different from those obtained when it was crossed with Reward. The figures given in table 7 for the cross Hope × Reward indicate that the resistance inhibitor possessed by Reward is also effective in this cross. The susceptible class was quite distinct, and very little difficulty was encountered in classification. The types of infec-

TABLE 8. *Observed and calculated ratios in the cross Hope × Reward. Assumption; two complementary factors and an inhibitor.*

F_2 genotype	F_2 phenotype	Observed	Calculated	O-C	$\frac{(O-C)^2}{C}$
AABBii	resistant	111	119.06	8.06	.54
AABbii					
AaBBii					
AaBbii	semi-resistant	232	238.12	6.12	.16
AABBII					
AaBBII					
AABbII					
Remainder	susceptible	1181	1166.81	14.19	.17
		1524			$\chi^2 = .87$
		$P = .66$			

tion are illustrated in Figure 4. An explanation based on the assumption that Hope carries two complementary factors A and B, and Reward a factor I capable of inhibiting the action of both is very satisfactory. In order to



Figure 4. Field reactions in the cross Hope × Reward. Left to right; Marquis, S, SR, R, Hope.

accommodate the semi-resistant class, it is necessary to assume that when factors A and B are both present, and one of them homozygous (i.e. three "doses" of resistant factors) the inhibitive effect of I is only partial. Table 8 contains the observed and calculated figures according to this hypothesis.

The fit is very good, P being equal to .66. These data afford strong evidence for the strictly complementary relationship between the two factors possessed by Hope. It is probable that the deviation from a 9:7 ratio in the Hope \times Marquis cross is a result of errors in classification.

Webster C.I. 3780 \times H-44-24.

Figure 5 illustrates the types appearing in the cross Webster C. I. 3780 \times H-44-24. The percentage infection of Webster is usually as high as with susceptible varieties; but the pustule type indicates some degree of resistance. In the F_2 generation the parental types were recovered, and in



Figure 5. Field reactions in the cross Webster \times H-44-24. Left to right; Webster, S, MS, SR, R, H-44-24.

addition semi-resistant and highly susceptible types. The assumption that Webster possesses a dominant factor B for moderate susceptibility which, when homozygous, is epistatic to the H-44-24 resistance factor A , affords a satisfactory explanation of the facts. A comparison between the obtained

TABLE 9. Observed and calculated classes in the F_2 generation of the cross Webster \times H-44-24.

F_2 genotype	F_2 phenotype	Observed	Calculated	O-C	$\frac{(O-C)^2}{C}$
AABb	R	112	124.8	12.8	1.31
Aabb					
Aabb	SR	80	82.2	2.2	.06
AABB	MS	203	208.0	5.0	.12
AaBb					
AaBB	S	270	249.6	20.4	1.67
aaBB					
aaBb					
aabb					
		665	$P = .37$	$\chi^2 =$	3.16

and expected classes according to this hypothesis is given in table 9. The P value of .37 indicates a very good fit.

Marquillo \times (*Marquis-Kanred* B_{2-5})

The last four crosses listed in table 7 are of interest in that they demonstrate the complexity of the inheritance of Marquillo resistance in crosses between Marquillo and susceptible varieties.

The cross Marquillo \times (*Marquis-Kanred* B_{2-5}) yielded a very low proportion of resistant plants. From the results of a study of F_3 lines of this cross, Hayes *et al* (11) concluded that the Marquillo resistance was governed by two main factors; but they suggest that modifying factors also operate. The plants classified as SR by the present authors showed a fairly high degree of resistance, though not equal to Marquillo in this respect. The ratios, therefore, certainly indicate the operation of more than two factors. This apparent disagreement can probably be accounted for by the fact that only nine physiologic forms of the stem rust organism were used in the artificial epidemic in the Minnesota study. Through the courtesy of Dr. Margaret Newton and Mr. T. Johnson, the authors were enabled to introduce over 20 physiologic forms into the epidemics of 1927 and 1928. It is probable, therefore, that the much lower proportion of resistant plants found in the present study is due to the presence of a larger number physiologic forms.

Garnet \times *Marquillo*

In the cross Garnet \times Marquillo only one plant in a sample of over 5000 possessed resistance equal to that of Marquillo. In the same year (1927) the field reaction of over 1000 F_3 lines was determined, and not one line proved equal to Marquillo in resistance.

Marquillo \times *Reward*

In this cross, also, it appears that several factors are concerned in the inheritance of Marquillo resistance. Only one F_2 plant of a total of 1598 was as resistant as Marquillo.

RELATION BETWEEN FIELD RUST REACTION AND OTHER CHARACTERS

Marquis \times *H-44-24*

In the 1929 study of the F_3 generation of the cross Marquis \times H-44-24 the presence or absence of awns was also recorded. Table 10 shows the distribution of F_3 lines according to awning and rust reaction. When the

TABLE 10. Distribution of F_3 lines of the cross Marquis \times H-44-24 for awning and field rust reaction.

		Awned	Awning Segregating	Tip-awned	
Field Rust	R	70	101	53	224
	Seg	158	363	177	698
	S	61	149	71	281
		289	613	301	1203

$$\chi^2 = 8.15$$

$$P = .087$$

awn classes are fitted to a 1:2:1 ratio a P value of .70 is obtained. When the relationship between rust reaction and awning is measured by the χ^2 test, $P = .087$. This indicates that the inheritance of these two characters is independent in this cross.

In 1928 leaf pubescence was recorded in addition to awning and rust reaction. The leaves of H-44-24 are quite densely pubescent, while those of Marquis are glabrous, or nearly so. Of a total of 270 lines, 21 bred true for the glabrous condition. On the basis of two independent factors operating to produce pubescence 17 glabrous lines would be expected. The deviation is 4 ± 2.35 , so there is little doubt that two factors operate. Tables 11, 12 and 13 show the relationships between the three characters studied. In all cases the inheritance is clearly independent.

TABLE 11. *Distribution of F_3 lines of the cross Marquis \times H-44-24 for field rust reaction and leaf pubescence.*

		Leaf Pubescence			
		Pubescent	Segregating	Glabrous	
Field Rust	R	21	35	4	60
	Seg.	41	86	8	135
	S	21	45	9	75
		83	166	21	270
		$\chi^2 = 3.25$		$P = .52$	

TABLE 12. *Distribution of F_3 lines of the cross Marquis \times H-44-24 for field rust reaction and awning.*

		Awning			
		Awned	Segregating	Tip-awned	
Field Rust	R	11	32	17	60
	Seg.	30	76	29	135
	S	18	37	20	75
		59	145	66	270
		$\chi^2 = 1.81$		$P = .77$	

TABLE 13. *Distribution of F_3 lines of the cross Marquis \times H-44-24 for leaf pubescence and awning.*

	Awning			
	Awned	Segregating	Tip-awned	
Pubescent	14	47	22	83
Segregating	38	90	38	166
Glabrous	7	8	6	21
	59	145	66	270
	$\chi^2 = 3.83$		$P = .43$	

H-44-24 × Reward

In this cross chaff pubescence and awning were recorded in addition to field rust reaction. The awning data do not agree well with a 1:2:1 ratio, P being equal to .03. However, the deviation from a 3:1 ratio of awned and segregating lines to tip-awned lines is only 12.75 ± 9.8 .

The question of the inheritance of the pubescent chaff of Reward requires further investigation. When the obtained ratio is fitted to a 1:2:1 ratio, $P =$ less than .01. The deviation of the ratio of pubescent and segregating to glabrous lines from a 3:1 is 30.75 ± 9.8 . That the three characters, awning, chaff pubescence and field rust reaction, are inherited independently is evident from the data contained in tables 14, 15 and 16.

TABLE 14. *Distribution of F_3 lines of the cross H-44-24 × Reward for awning and field rust reaction.*

		Awning			
		Awned	Segregating	Tip-awned	
Field Rust	*R	21	51	19	91
	R:S	25	95	44	164
	S:R	100	247	134	481
	S	97	195	97	389
		243	588	294	1125
		$\chi^2 = 8.73$		$P = .191$	

*For key to symbols, see discussion of inheritance.

TABLE 15. *Distribution of F_3 lines of the cross H-44-24 × Reward for chaff pubescence and field rust reaction.*

		Chaff Pubescence			
		Pubescent	Segregating	Glabrous	
Field Rust	R	14	39	38	91
	R:S	32	86	46	164
	S:R	106	246	129	481
	S	87	203	99	389
		239	574	312	1125
		$\chi^2 = 10.74$		$P = .098$	

TABLE 16. *Distribution of F_3 lines of the cross H-44-24 × Reward for awning and chaff pubescence.*

		Chaff Pubescence			
		Pubescent	Segregating	Glabrous	
Awned		61	113	69	243
Segregating		115	311	162	588
Tip-awned		63	150	81	294
		239	574	312	1125
		$\chi^2 = 3.91$		$P = .420$	

DISCUSSION

Probably the most significant feature of the results presented is the simplicity of the inheritance of the high resistance of H-44-24 and Hope. It appears that this character may be handled as easily by the plant breeder as any morphological character. The different behaviour of Hope from that of H-44-24 is quite striking. The results indicate that the Hope resistance is governed by two factors quite distinct from the H-44-24 factor. The contrasted behaviour of Marquis and Reward is also of considerable genetic interest. In crosses involving these four varieties, some of the ratios do not agree very well with the theoretical ratios proposed. Certain facts, however, are fairly well established. Reward undoubtedly carries a factor capable of inhibiting the action of both H-44-24 and Hope resistance factors. It is equally certain that the inheritance of the Hope resistance is more complicated than that of H-44-24.

In the case of resistance derived from the durum variety Iumillo, the contrast is very marked. Any breeding programme depending upon this resistance necessitates the study of a much greater number of hybrid plants. However, resistance derived from durum varieties is not necessarily complicated. Goulden (6) has transferred the resistance of Pentad to *vulgare* types. This resistance is apparently inherited as a unit character, and is of as high a type as that possessed by Hope or H-44-24.

SUMMARY

Data are presented on the inheritance of resistance to stem rust in the field. Eleven different crosses are included in the study.

In the cross Marquis \times H-44-24 field resistance is governed by a single factor. Deviations from a ratio based on a single factor difference are probably due, chiefly, to natural crossing in the F_2 generation.

Resistance in the cross Marquis \times Hope appears to be governed by two complementary factors.

Results obtained in crosses between Reward and Hope and between Reward and H-44-24 reveal a factor in Reward capable of inhibiting the action of the Hope and H-44-24 factors for resistance. Results in these crosses also support the conclusion that the H-44-24 resistance is governed by a single factor pair, and the Hope resistance by at least two pairs.

From a study of F_2 and F_3 generations of the cross Marquillo \times H-44-24 it appears that in addition to the H-44-24 factor for resistance, two or more factors are contributed by Marquillo.

The assumption that Double Cross carries two complementary recessive factors for resistance explains the results obtained in the cross Double Cross \times H-44-24 very well.

Results obtained in the F_2 generation of the cross H-44-24 \times (Marquis-Kanred B_{2-5}) indicate that the field rust reaction is governed by a single pair of factors.

Two factors are concerned in the inheritance of resistance to stem rust in the cross Webster \times H-44-24. Webster contributes a dominant factor for moderate susceptibility, which when homozygous is epistatic to the H-44-24 factor for resistance.

In crosses between Marquillo and susceptible varieties, a very low proportion of resistant plants appears in the F_2 generation. When Marquillo is crossed with Marquis-Kanred B_{2-5} , the operation of three or more factors is indicated. If the cross is made with Reward or with Garnet many factors are involved, and only by growing very large numbers of F_2 plants can the Marquillo resistance be recovered.

The relation between awning and field rust reaction was studied in the two crosses H-44-24 \times Reward and Marquis \times H-44-24. The two characters are inherited independently in both crosses.

Chaff pubescence was studied in relation to field rust reaction and awning in the cross H-44-24 \times Reward. There was no indication of linkage.

In the cross Marquis \times H-44-24 leaf pubescence was studied in relation to field rust reaction and awning. The three characters were all inherited independently.

ACKNOWLEDGMENT

The authors are indebted to Mr. R. F. Peterson, student assistant, for valuable assistance in the various phases of the investigation.

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THE RELATION BETWEEN STEM RUST INFECTION AND THE YIELD OF WHEAT *

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In previous studies on the influence of rust on the yield of cereal crops the method employed has been to correlate rust percentage with yield in a heterogeneous group of varieties and strains. Among such groups there are varying degrees of rust resistance and consequently varying percentages of rust are obtained which can be correlated with yield. These studies have given quite definite results. Goulden and Elders (4, 1926), with a group of 146 wheat varieties, studied all possible relations between yield, susceptibility to stem rust, susceptibility to leaf rust, earliness, and strength of straw. They obtained the partial correlation coefficient — $.722 \pm .027$ for the relation between yield and susceptibility to stem rust, and — $.456 \pm .044$ for yield and susceptibility to leaf rust; Hayes, Aamodt, and Stevenson (6, 1927), in a similar study, found stem and leaf rust to be quite significantly associated with the yield of spring wheats and that stem rust was significantly associated with the yield of winter wheats. From data on a group of oat varieties and strains, Immer and Stevenson (7, 1928), found a significant association between crown rust and yield.

The method of correlating rust percentage with yield in a heterogeneous group of strains has given results demonstrating the extreme importance of rust as a factor in cereal crop production and of the concurrent importance of the use of resistant varieties. However, as pointed out by Goulden and Elders in 1926—"in the interpretation of these results it must be borne in mind that the data were obtained from a group of wheat varieties which one would not be justified in assuming to be a random sample." The results were quite definite for the material studied but with another and entirely distinct group of varieties the value of the correlation obtained might be somewhat different. This point may be more clearly brought out by the consideration of a theoretical case. Let us assume that the varieties tested may be divided into four categories on the basis of rust resistance, these categories being (1) resistant, (2) moderately resistant, (3) moderately susceptible and (4) susceptible. Obtaining a true correlation value between the amount of rust and yield is then based on the assumption that the intrinsic yielding capabilities of the four groups, i.e. their average yields when rust is not a factor, are approximately the same. If the resistant varieties give lower yields than the susceptible varieties when rust is not a factor, the numerical value of the correlation coefficient will be too low; and conversely, if the resistant varieties are the best yielders under such conditions, the numerical value of the correlation coefficient will be too high.

It was these facts which were generally referred to, in the 1926 publication, in the statement regarding the inadequacy of the heterogeneous

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group of varieties as a purely random sample. They have led furthermore to the planning of an experiment in which the different amounts of rust on a *single standard variety* could be correlated with yield. The information from such an experiment it was thought would be of considerable value in estimating yields for crop reports. There seems to be a tendency in estimating rust losses to neglect entirely the effect of a ten or fifteen per cent infection of rust. Consequently experimental results showing the exact effect of such small infections should materially assist in the process of estimation.

EXPERIMENTAL METHODS

The main part of the experiment was conducted on a block of land sown to Marquis wheat and divided into 196, 1/400th acre plots. These were arranged in the form of a 14×14 Latin Square in which the amounts of rust on different replicates were varied by different rates and frequency of application of sulphur dust. Previous experiments, Bailey and Greaney (1, 1925, 2, 1928), and Greaney (5, Rept. of Dom. Bot., Can. Dept. Agr. 1928), had indicated that by such treatment all gradations of rust infection could be obtained and it seemed, therefore, to be a very convenient method to apply for the purpose of this study. In the 14×14 Latin Square, 13 treatments were worked out, the 14th being the check which was left untreated. The treatments were as given in table 1.

TABLE 1. *Different methods of treating plots of Marquis wheat with sulphur dust in a 14×14 Latin Square in order to give varying percentages of rust.**

Treatment No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Amount of dust per acre in lbs.	15	15	15	15	15	30	30	30	30	45	45	45	45	0
Interval between applications in days	21	14	7	4	2	14	7	4	2	14	7	4	2	

*the degrees of rust in these plots were read according to the U.S.D.A. standards where 37 per cent of actual surface covered with rust is arbitrarily chosen as 100 per cent.

The results from two other experiments which were conducted by the junior author primarily for the purpose of comparing the efficiency of different methods of treatment and of different kinds of sulphur dust for the control of rust, were also incorporated in the present study. These experiments were likewise arranged in the form of Latin Squares, the plots being 1/200 acre in size. The first was an 8×8 Latin Square in which four methods of treatment were compared and three kinds of sulphur dust. The second was a 7×7 Latin Square in which six kinds of dust were compared directly. The different treatments given in these two squares are listed in table 2. These treatments are given in table 2 merely as a general indication of the treatments the varying effectiveness of which brought about varying amounts of rust in the plots. Complete details of these experiments and the results obtained are given by Greaney in as yet unpublished data.

TABLE 2. *Different sulphur dust treatments given plots of Marquis wheat in two experiments conducted in 8 × 8 and 7 × 7 Latin Squares.*

Type of Latin Square	TREATMENTS							
	No. 1	2	3	4	5	6	7	8
7 × 7	Kolodust	Koppers dust	Electric dust	Kopper's + lime	Sulfo-dust	Gas dust	None	
8 × 8	Kolodust before rains	Kolodust after rains	Kolodust direct dusting	Kolodust drifting	Commer-cial oxidized dust	Kolodust + Oxide 2%	Kolodust + Oxide 5%	None

RESULTS AND DISCUSSION

In the analysis of the results from these two experiments rust percentages and yields of individual plots were correlated. In the 14 × 14 experiment the rust percentages varied from zero to 70 per cent although only one plot gave the latter figure and the next highest was 50 per cent. The crop on this block, owing to the drought experienced during the 1929 season, was fairly light. The drought also served to check the development of a heavy rust epidemic. In making a correlation surface for the rust percentages and yields in this block all those plots were discarded which failed to give as high as 5 per cent of rust. There were 85 such plots so that the total number on which data could be obtained was 111.

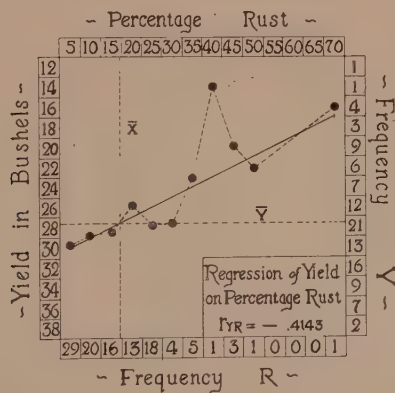


Figure 1. Regression of yield on percentage rust in plots of Marquis wheat in a 14 × 14 Latin Square.

The results from the 14 × 14 Latin Square are given in the form of a regression graph in Figure 1. The correlation coefficient for this group was —.4143. Its significance was tested by the method given by Fisher (3). This involves calculating—

$$t = \frac{r}{\sqrt{\frac{1 - r^2}{n - 1}}}$$

where n^1 is the number of pairs of values entering into the correlation. For our coefficient $-.4143$ the value of t is 5.24. Using Fisher's tables, it is evident that the odds of significance are considerably greater than 100:1 as for these odds a t value of only 2.6 is required. The determination of the regression of yield on percentage rust, while not entirely satisfactory on account of the low frequency of plots with high rust percentages, gives, however, an approximate value for the reduction in yield corresponding to a given increase in the percentage of rust. Here the reduction in yield for each 10 per cent increase of rust is 1.97 bushels. It seems most logical to express this value in per cent of the average yield (28.4 bushels,) of the highest yielding series in the experiment. The highest yielding series was the one given the heaviest sulphur treatment and as nearly as possible represents what the average yield of the entire block would have been if rust had not been present. The reduction of 1.97 bushels represents 6.8 per cent of 28.4 bushels.

In the second experiment the results from the 7×7 and 8×8 blocks were combined. These two blocks were very much alike in average yield and average percentage of rust so that combining the results could have only a very slight spurious effect on the value of the correlation coefficient. In fact, in making up the correlation table the blocks were dealt with separately and the swarm of one superimposed on that of the other. The two swarms coincided very closely and easily justified the combination of the two sets of data. The value of the correlation coefficient obtained in this experiment was $-.6085$ for which the value of t is 10.2. Again this is a very significant value. The regression graph is shown in Figure 2 and we find that for 10 per cent increase of rust the yield is reduced by 3.83 bushels. This is 9.7 per cent of 39.3 the yield in bushels of the series having the most effective treatment for rust control.

The two results considered from the standpoint of the per cent reduction in yield for each 10 per cent of rust are very significant and give us an approximate measure of the reduction in yield to be expected under ordinary conditions. An important point is the uniform reduction in yield as the rust varies from low to high percentages. From the standpoint of the regression graph this is a matter of linearity of regression. To test this the analysis of variance method as developed by Fisher (3) was used. In both cases the deviations from the regression straight line are not significant, and this indicates that 10 per cent of rust will reduce the yield to the same extent as an increase in rust from 70 to 80 per cent.

A point of further interest is the difference between the values of the correlation coefficients from the two experiments. On the basis of per cent reduction in yield, the one experiment giving 6.8 per cent and the other 9.7 per cent, the difference does not seem very great but that it is probably significant is evident from a comparison of the correlation coefficients. Applying the z test as developed by Fisher (3), we find that z for the difference is $.26576 \pm .13546$. Thus z is 1.96 times its standard deviation and this is equivalent to odds of 20:1. Where the average yield is high the average percentage of rust is high and the reduction in yield per 10 per cent of rust correspondingly greater than where the average yield and rust percentage

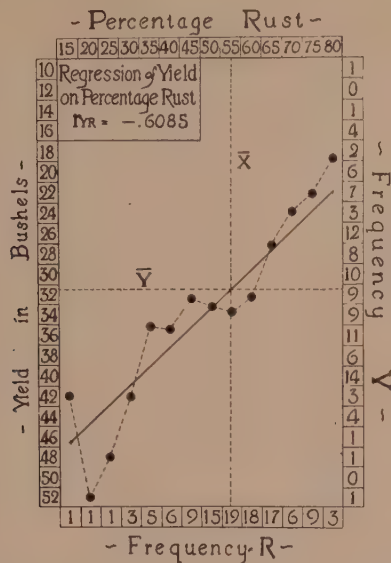


Figure 2. Regression of yield on percentage rust in plots of Marquis wheat from 7 × 7 and 8 × 8 Latin Squares.

is somewhat lower. The straight line regression indicated that for any given set of conditions especially with respect to the heaviness of growth, the relation between amount of rust and reduction in yield is linear but on another field where growth is heavier, while the relation is still linear, the reduction caused by a given amount of rust may be greater than where the growth is light. These points while not definitely proven are certainly indicated by the data from the above experiments.

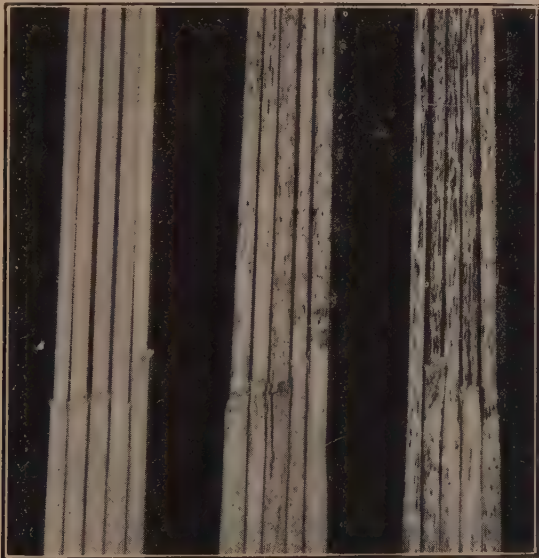


Figure 3. Three samples of Marquis wheat straw from the plots of the 7 × 7 and 8 × 8 experiments showing the range in rust infection. From left to right these infections were read, 0%, 40%, and 80%.

SUMMARY

1. The amounts of rust in a series of plots of Marquis wheat were varied by different rates and intervals between applications of sulphur dust. The yields of individual plots were then correlated with the rust percentages.

2. The results from two such experiments are summarized in the form of correlation coefficients and regression equations. In one experiment it was found that each 10 per cent of rust reduced the yield approximately 6.8 per cent, and in the other experiment each 10 per cent of rust reduced the yield 9.7 per cent.

3. In both experiments the regression of yield on percentage rust was linear, indicating that uniform increases in rust result in uniform reductions in yield.

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FARM MANAGEMENT RESEARCH IN SASKATCHEWAN*

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Saskatchewan, the central province of the Canadian prairies, has an agricultural area of about 300 miles north and south, by 400 miles east and west. Official estimates claim about fifty-eight million acres suitable for cultivation, of which about half (26.6 million acres) have been prepared for crops.‡

For many centuries the North American Indians had been the sole occupants of Saskatchewan. Indian names appear frequently on maps of the province. Trading posts had been established by agents of the Hudson's Bay Company many years before Confederation (1867). To oppose settlement of the prairies in organized revolt Reil staged the first rebellion in 1869. After a moderately quiet spell, during which settlement gradually spread westward, Reil led his second rebellion in 1885, which was the last stand of the primitive order resisting the settlers. News of these conflicts spread widely, advertised the territories, and helped in settlement.

When the eastern provinces were confederated in 1867, the new Dominion acquired the unorganized British possessions of Western Canada. To induce British Columbia to enter Confederation, the Dominion agreed, in 1871, to complete a transcontinental railway line within ten years. The railway was started as a government project in 1874, but little progress was made during the next six years. In 1880, to hasten the project, a contract was made with the Canadian Pacific Company to complete the line before 1891, which was actually accomplished by May 1, 1885. For its work the company received some \$25,000,000 cash, and 25,000,000 acres of land. This railway was built through Saskatchewan about 1882, and helped materially in the settlement of the province.

Manitoba development preceded that of Saskatchewan. For many years it contributed much of the world's finest hard red spring wheat, and gave its name to the wheat grade of Western Canada. The centre of Canadian wheat production has since moved westward to Saskatchewan, which, with Alberta, produces the bulk of the hard spring wheat of the prairies.

Manitoba was recognized as a province as early as 1870. Saskatchewan developed later, not being created a province until 1905, when its population was about a quarter of a million. Nearly two-thirds of its people had been gained by immigration during the preceding five years.

Immigrants continued to settle in Saskatchewan in large numbers until the European war commenced. By 1916 the population was nearly 648,000, and most of the desirable crown lands had been appropriated through homesteading. The population in 1929 is estimated at about 900,000 and the number of farms is about 118,000. Between 1921 and 1926, according to the data of the Census, the number of farms in Saskatchewan had decreased by some

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‡Report of Secy. of Statistics, Dept. of Agric., Sask., 1928.

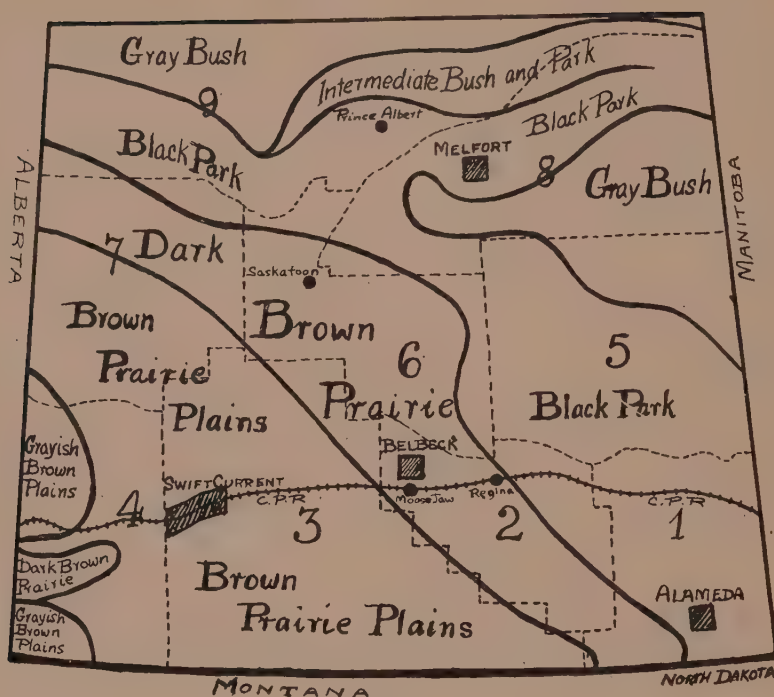


Figure 1.

The heavy lines indicate the approximate boundaries of the major soil belts. The numbers refer to crop districts, the boundaries of which are shown with dotted lines.

The blocked sections at Belbeek, Melfort, Alameda, and Swift Current show the areas included in the farm business surveys.

1500, with an increase in the total land in farms, and in the average size of farms.

TYPES OF FARMING IN SASKATCHEWAN

The agricultural section of the Province of Saskatchewan comprises an area of some 100,000 square miles, within which there are six major soil belts.* The extent and general location of these belts are indicated in the accompanying map.

The major types of farming are linked up with the natural conditions of soil and climate. The northern bush lands play little part in farming, and generally support heavy tree growth. The most northerly agriculture which is in any way extensive is established on the wide stretches of black park lands. Extensive prairie belts comprise the balance of the area.

The natural vegetation varies from the sparse growth of short grass on the semi-arid plains of the southwest, to the generous park and bush growth of the north and east. The highest precipitation is in the east and the lowest is in the west.

The high winds from the south-west which pass over the prairie belts are hot and dry. They cause rapid evaporation and seriously restrict plant

*Outlined by Dept. of Soils, University of Saskatchewan.

growth. Although these winds affect the whole province to some extent they are generally most severe in the south-west, gradually decreasing in severity with further travel.

Within the major soil belts are very wide variations in soil character and topography. The best lands for farming are the level or slightly rolling clay or loam soils situated on satisfactory subsoils. Coarse sand or gravel subsoils permit the dissipation of soil moisture, impairing plant growth.

Wheat is grown in Saskatchewan wherever practicable. It is subject to the limitations of late spring and early fall frosts, wheat stem rust and other diseases, and insect pests. The best pasture and forage crops are found in the more humid areas, but even with possibilities of considerable livestock enterprises, wheat and other grains provide the major portions of the cash income of the farmer.

On some of the sandy lands of the south-west, fall rye and livestock enterprises have been found the most satisfactory, particularly during seasons of limited rainfall. The desire to grow wheat persists, and following a few seasons of comparatively generous rainfall, wheat takes the place of rye, usually with serious financial consequences.

The driest and most broken lands find their best uses as ranges for stock. Many areas which made satisfactory ranges were broken up into farms for which they were quite unsuited, usually being abandoned after many years of discouragement. Personal, social and economic losses resulting from this mistaken land settlement policy have been tremendous.

Two years after the creation of the province the University of Saskatchewan received its charter. Instruction commenced in temporary quarters in 1909. The first buildings were completed in 1912. From the opening of the University the College of Agriculture has been included with the other colleges on the University campus at Saskatoon.

The Department of Farm Management was provided for in 1925. Course work and general departmental activities occupied most of the time of the first year. The collection of data from Saskatchewan farms, by surveys of farm business, commenced the following summer.

The summer of 1926 was a busy one. Surveys were made on the heavy clay lands of the Regina plains, and in the northern branch of the park belt. Both areas had been included in soil surveys. The districts were fairly well established and the farmers were all English speaking. Two students, graduates of the College of Agriculture, assisted in the collection of data.

The Belbeck district, north of the city of Moose Jaw, was visited first. The soil conditions of this area are quite uniform, and similar to many areas of the Regina plains. The results obtained at Belbeck are free from many influences generally found where conditions are less uniform. In some respects this uniformity permits the study to be used as a check for succeeding studies.

After completing the field work of the Belbeck farms, the party moved to Melfort and collected reports of about one hundred farms. This area is a successful settlement of English speaking people on the good soils of the northern park belt.

During the winter of 1926-1927 the data of the Belbeck survey were prepared for analysis, and a report was published as Agricultural Extension Bulletin No. 37 of the University of Saskatchewan. The report of the Melfort area was delayed by other work until the following year, when it appeared as Bulletin No. 43 of the same series.

The Alameda district, in the south-east corner of the province, and near the south end of the park belt, was visited for a farm business survey in 1927. Data were secured from one hundred farms. The report covering this area will be published shortly.

The field work of a farm business survey was undertaken in the Swift Current-Gull Lake district, in the brown plains belt, during 1928. Progress has been made with this study, but publication of the report is not expected before 1930.

The season for field operations for Saskatchewan farm surveys is limited to the latter part of June, July, and the early part of August. This is the period between the completion of seeding and the commencement of harvesting. Saskatchewan has dirt roads which are satisfactory in dry weather, but after spring thaws or heavy rains are usually difficult to travel. Farms are large and travelling makes heavy demands on time and funds.

The numbers of farms visited have decreased somewhat with successive surveys in spite of efforts made to increase them. A larger number of farms would be desirable. In the first surveys attempts were made to secure as many farms as possible within the area. Some omissions were necessary. The last field study, Swift Current-Gull Lake, included only farms reasonably successful during the preceding financial year. Frost and hail had played havoc with crops on many farms in this district in 1927, and these were not included. Other complications included community settlements of Mennonites, language difficulties, and abrupt topography and soil variations.

STATISTICAL SUMMARY OF SASKATCHEWAN STUDIES

Table 1 contains sections summarizing the studies made in Saskatchewan up to 1929. They permit a rapid survey of the different areas, and of the major types of farming of the province. In general rainfall is the major limiting factor to high crop yields in each of these areas. Moisture is usually ample if conserved, and inadequate if permitted to escape. Evaporation makes great differences in productive possibilities.

Weeds dissipate moisture rapidly, as well as deprive crops of plant food. The control of weeds has become one of the most serious problems of the farmer.

Late spring and early fall frosts occasionally make farmers' efforts fruitless. In 1928, an early frost in August caught the excellent wheat crop, and produced an average grade of No. 4, or No. 5, instead of a normal No. 2, or No. 3, and at the same time materially decreased the yield and complicated the marketing operations.

Rust has proved a serious menace to the wheat crop of the prairies. It cost the farmers millions of dollars in 1927.

Dry weather, with hot winds during the growing seasons of 1927 and 1929, reacted seriously on the crops of many sections of Saskatchewan and Alberta.

The recital of the adverse factors which have to be considered is not intended to portray pessimism. In many areas of the prairie provinces farmers have built up farm businesses from very little initial capital which compare favourably with results obtained from farming operations elsewhere. This paper attempts to portray farming under some of the major type classifications.

In all parts of Saskatchewan the emphasis is decidedly on raising grain crops. Diversified farms are exceptional. Most farmers grow as much wheat as possible, as livestock enterprises do not appeal generally to the average farmer. Oats and barley rank next to wheat in importance. Where sandy soils have been found to drift with the high winds fall rye has proved of considerable value in checking erosion. Mechanical power and larger machines and implements are becoming more common on prairie grain farms during recent years.

The capital values of these farms are significant. Where there is a high percentage of borrowed capital progress is extremely slow. The prices of lands in Saskatchewan did not advance as much during the war as in some nearby states, but in many sections of the province land prices should be considered out of line with their productive capacities. Settlements on lands useless for grain production have caused much distress, and government aid has been necessary to help people move away from some of the driest sandy areas of the southwest.

Land values and building values vary greatly, as indicated by the average estimates for each study. Changes in farm practice may render useless buildings, as well as machinery, but in general the kind and condition of buildings reflect the success of agriculture on the prairies.

The greatest uniformity of investment in each area, appears in the livestock estimates. Melfort and Alameda might be considered naturally suited to livestock farming, but this is not reflected in the number of animals present. In most cases the animals kept are practically limited to work horses, and the domestic animals required for farm needs.

There were wide ranges in the number of men available for farm work on comparatively similar farms, but group averages for the different areas show only small differences. Labor was probably used more efficiently on the rather poorer area of Alameda than in the more prosperous areas of Belbeek and Melfort.

The burden of taxation in developing new communities and providing ordinary necessities is comparatively heavy. When this is related to land values, assumed to be associated with their earning capacities, the heaviest tax burden is seen to fall on the poorest land where the community advantages are severely limited.

From these first studies the advantages of a farm decidedly larger than the average were apparent for Saskatchewan conditions. Yields somewhat better than the average decreased costs per unit and increased profits. The farms using men, horses, equipment, and land most efficiently generally showed the lowest production costs, and the best financial reports.

TABLE 1. *Statistical Summary of Farm Management Studies*

1. District	Belbeck	Melfort	Alameda	Swift Current	Swift Current
2. Crop year studied	1925-6	1925-6	1926-7	1927-8	1927-8
3. Soil	Heavy Clay	Silty clay loam	Loam	Loam	Sand
4. Topography	Level	Slightly rolling	Slightly rolling	Rolling	Rolling
5. Field obstructions	Free	Scrub, wet spots	Scrub, wet spots	Miscellaneous	Miscellaneous
6. Rainfall, annual	14.6"	14.9"	15"	14.8"	14.8"
7. Rainfall, April-July	7.7"	9.8"	9"	7.8"	7.8"
8. Windiness and evaporation	Medium	Moderate	Moderate	High	High
9. Growing season, (days)	120	110	120	120	125
10. Frost free period (days)	97	80	90	96	96
11. Natural vegetation	Short prairie grass	Trees, good grass	Trees, - good grass	Short grass	Short grass
12. Quality of pastures	Poor	Fair	Fair	Poor	Poor
13. Water supply	Ponds — poor	Sloughs, rain water	Wells — good	Wells — fair	Wells — fair
14. Farms studied	119	106	100	82	14
15. Total farm area (average acres)	487	465	563	772	713
16. Cropland (acres per farm)	448	324	417	596	540
17. Crops, (acres per farm)	289	269	310	399	414
18. Wheat	207	157	136	318	284
19. Oats	59	62	80	62	56
20. Barley	16	34	43	1	—
21. Flax	2	—	15	4	—
22. Rye	—	—	8	3	—
23. Summerfallow	158	50	101	194	58 Fall 13 Spring
24. New breaking	1	5	5	3	126
25. Total capital per farm	\$34,368	\$24,643	\$16,847	\$32,950	— (1928) (38)
26. Land value	22,810	15,562	10,112	22,383	\$19,735
27. Buildings value per farm	6,483	4,651	2,923	5,519	10,719
28. Equipment	2,970	2,492	2,001	3,102	4,289
29. Livestock	2,105	1,938	1,811	1,946	3,024
30. Land value per acre	\$46.82	\$33.47	\$17.96	\$28.99	1,703
31. Land value, per acre crop land	50.91	48.04	24.25	37.55	\$15.03
32. Buildings, per acre crop land	14.47	14.35	7.01	7.94	19.85
33. Equipment, per acre crop land	6.63	7.69	4.80	5.20	7.94
34. Livestock, per acre crop land	4.70	5.98	4.34	3.27	5.60
35. Total capital per acre crop land	76.71	76.06	40.40	55.28	3.15
					36.54

TABLE 1. (Continued) Statistical Summary of Farm Management Studies

	Belbeck	Melfort	Alameda	Swift Current	Swift Current
36. Man equivalent	21.8	25.7	25.5	23.9	26.
37. Acres of crop land per man	13	11.08	10.8	15.8	15.
38. Livestock, (total animal units per farm)	(33)	(44)	(50)	(40)	(40)
39. Work horses per farm	4.4	6.1	6.7	3.9	5.9
40. Colts, A. U.'s per farm	2.2	4.2	4.7	2.	2.
41. Cows per farm	0.16	0.38	(67)	(45)	(6)
42. Other cattle A. U.'s per farm	0.84	2.08	1.29	0.65	0.17
43. Brood sows, " " "	0.21	(3)	(8)	(2)	0.24
44. Other hogs, " " "	0.69	0.49	0.55	0.13	(1)
45. Sheep	34.5	27.5	38.6	37.7	36.
46. Poultry	20.6	12.6	16.4	24.9	20.8
47. Acres of cropland, per work horse	\$7739	\$6752	\$5978	\$9099	\$9348
48. Acres of cropland per A. U.	7123	6002	4890	8226	8024
49. Total cash receipts per farm	6805	5346	3651	7952	6951
50. Receipts from crop sold per farm	69	74	79	35	7
51. Cash wheat sales per farm	(119)	(106)	(100)	(82)	(14)
52. Farmers selling dairy products	87	43	67	42	9
53. Receipts per farm dairy products	(119)	(106)	(100)	(82)	(14)
54. Farmers selling eggs	\$265	\$378	\$501	\$282	\$320
55. Receipts per farm, eggs	29	27	32	29	6
56. Receipts per farm from stock sales	(119)	(106)	(100)	(82)	(14)
57. Farmers custom threshing	\$2805	\$2614	\$2541	\$3694	\$4050
58. Threshing receipts per farm	\$6.26	\$8.07	\$6.09	\$6.20	\$7.50
59. Total operating expenses per farm	\$1078	\$1063	884	\$1425	\$1512
60. Total operating expenses per acre cropland	\$2.41	\$3.28	\$2.12	\$2.39	\$2.80
61. Value labor and board (ex. operator)	\$180	\$191	\$198	\$281	\$252
62. Value labor and board per acre cropland	\$0.40	\$0.59	\$0.47	\$0.47	\$0.47
63. Taxes paid per farm	7.9	12.3	19.6	12.5	23.5
64. Taxes paid per acre of cropland					
65. Taxes per \$1 land value (mills)					

*2 sold \$4300 of milk and cream

5 others sold \$715 of milk and cream

12 averaged \$59 per farm

Sections 38 to 46: The figures in brackets indicate the number of farms having that class of livestock. The calculations are made on the basis of all the farms included in the study.

Sections 52 to 58: The figures in brackets show the number of farms included in each study. The amounts which follow are calculated on the basis of all the farms.

One year's results provide only the beginning of serious study and alone may prove misleading, as results vary greatly from year to year. In the Alameda district, where farm lands are valued at about \$18. per acre, the average labour income on 100 farms for the 1926-1927 crop year, was \$2445. This was probably the best year these farmers had experienced for a decade.* On the basis of yields and grades of the crop district, and average prices received, the index of the proceeds of sales per acre (1917-1927=100) from 1917 on, was 142, 117, 76, 40, 114, 60, 98, 113, 154, 81.

Saskatchewan farmers suffer from the extreme variations in conditions.† In the Saskatoon crop district the approximate number of acres of wheat required to pay taxes on a 320 acre farm varied from 3.37 in 1917 to 18.95 in 1924, and other farm costs varied in much the same way.

At this time it would not be generally advantageous to put anything in the place of wheat growing, but under many conditions complementary enterprises would be profitable. The farmer should neglect no possible source of profit, but should avoid work which makes no contribution to the general and permanent success of the farm.

Farm management research in Saskatchewan is in its infancy and the field is large. Through the provision of the Agricultural Research Foundation a study of dairying on Saskatchewan farms has been made this year (1929), under the direction of Dr. E. G. Misner of the Department of Agricultural Economics and Farm Management at Cornell University. This study was intended to include the marketing of Saskatchewan dairy products.

Many agencies are at work to improve the agriculture of the province and to benefit the farmers. Coöperative ventures have been characteristic of the province, and of the prairies in general, the most outstanding being the provincial Coöperative Wheat Producers, commonly known as the Pool. Coarse grains are marketed coöperatively through coarse grain pools. Practically all agricultural products are provided with facilities for coöperative marketing.

*Based on reports of Secy. of Statistics, Dept. of Agric., Regina, Sask.

†Based on the unpublished data collected by the Dept. of Farm Management, University of Saskatchewan.

EARLY VERSUS LATE PLOUGHING OF SWEET CLOVER FOR GREEN MANURE.

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"Seeing that it is more convenient to plough early, will the increase in nitrogen content of my sweet clover green manure crop for tobacco, pay me to leave the ploughing in as late as possible when it is more inconvenient to do the work?"

The above is an enquiry we received some time ago from an Ontario farmer who specializes in growing tobacco. We could not find specific information on this point in the literature available, and so planned the investigation here reported.

A field of white sweet clover on the college farm, seeded down with oats the last week of April of the previous season (1928), supplied us with material for the investigation.

The total nitrogen content of the sweet clover plants, roots and tops separately, was determined weekly, beginning April 26th, when the sweet clover had nicely started growth, and continued until June 17th, when the plants were over two feet high.

PROCEDURE

Five average sized plants were selected for each nitrogen determination. Care was taken to dig deeply to obtain as much as possible of the roots without breaking any away. These were washed and the roots cut from the tops. Roots and tops were measured and the average size was recorded. Roots and tops were separately cut up into small pieces and placed on flat trays to be dried in an oven kept at 50°C. When completely dry they were carefully weighed. One gram of each was taken as a representative of the whole, in making the nitrogen determinations. The tests were run in triplicate, and when there was a variation, as there was on two occasions, the average of the three was recorded.

The "Modified Gunning" test for total nitrogen (including the nitrates) was used. This is a modification of the Kjeldahl test outlined in the U.S. Department of Agriculture Official and Provisional Methods of Analysis.

RESULTS

TABLE 1. *The amount of nitrogen (as N₂) per gram, and the total N₂ of the tops.*

Date	Sample	Height (inches)	Weight (in grams)	N ₂ per Gram (in grams)	Total N ₂ of 5 Tops (in grams)
Apl. 26	1	21½	4.7	0.035	0.164
May 3	2	31½	8.0	0.036	0.288
" 10	3	6	11.0	0.033	0.363
" 17	4	7	16.8	0.0385	0.6468
" 23	5	10	31.0	0.04018	1.24558
June 1	6	13	39.5	0.0378	1.49
" 8	7	18	46.8	0.039	1.82
" 17	8	24	55.5	0.0419	2.325

TABLE 2. *The amount of nitrogen (as N₂) per gram, and the total N₂ of the roots.*

Date	Sample	Length (inches)	Weight (in grams)	N ₂ per Gram (in grams)	Total N ₂ of 5 Roots (in grams)
Apl. 26	1	5	3.0	0.0319	0.095
May 3	2	6	4.7	0.028	0.131
" 10	3	9	4.4	0.021	0.092
" 17	4	10	7.0	0.0273	0.191
" 23	5	11	8.6	0.019	0.163
June 1	6	11	14.0	0.021	0.294
" 8	7	11½	17.0	0.021	0.375
" 17	8	13	10.0	0.0175	0.175

TABLE 3. *Total weights of N₂ per gram, and total N₂ of roots and tops in grams.*

Date	Sample	N ₂ per Gram	Total N ₂ for Five Plants	Estimates made on basis of 25 plants per sq. yd.
Apl. 26	1	0.0669	0.259	13.8
May 3	2	0.064	0.419	22.3
" 10	3	0.054	0.455	24.2
" 17	4	0.065	0.837	44.6
" 23	5	0.0608	1.428	76.1
June 1	6	0.0588	1.784	95.1
" 8	7	0.06	2.177	116.1
" 17	8	0.058	2.506	133.1

TABLE 4. *Total nitrogen (Pounds per acre).*

DISCUSSION

A study of the tables shows that while there was a general increase in the nitrogen contents of the plants, this increase was not altogether uniform week by week. For this lack of uniformity of increase several factors may be considered responsible. First, the rate of growth would not be uniform week by week owing to variation of atmospheric and soil conditions, as temperature and moisture. Second, some difficulty would be met with in securing five strictly average plants on each occasion. Third, on the occasions when the soil was dry and hard there would be a tendency for portions of the root to be broken off when being dug.

It will be noticed in the tables that the increase in nitrogen content was found in the tops rather than in the roots. In the roots there was an actual decrease of nitrogen per gram of substance, although the amount of nitrogen for the entire root increased with the increase of size of the root. With the tops, however, there was an increase of nitrogen per gram of substance, as well as the increase of nitrogen of the entire top due to increase in size of plant. In the field from which the plants were taken there averaged twenty-five sweet clover plants per square yard. The estimates of nitrogen in pounds per acre recorded in table 4 are based on that factor.

By a study of table 4 it will be seen that in the four weeks from April 26th, to May 23rd, there was an increase of from 13.8 to 76.1 pounds of nitrogen per acre in the crop, an increase of 550 per cent. During the next three and a half weeks this amount of nitrogen was again nearly doubled, jumping from 76.1 to 133.1 pounds per acre.

What percentage of this increase of nitrogen in the plants was obtained from the nitrogen of the atmosphere through the agency of the legume bacteria, we cannot say. Nodules were generally numerous on the plant roots, thus indicating that the bacteria were present and probably active in enabling the plants to fix atmospheric nitrogen. But it is also probable that some, at least, of this increase of nitrogen in the plants was at the expense of nitrates present in the soil. Some of the increase of nitrogen in the tops was at the expense of that stored in the roots as indicated by the lowering of the nitrogen content per gram of root tissue.

A factor to be considered in connection with deferring ploughing in order to get a heavier crop to turn in, is the time necessary for the decay of the crop after it is ploughed. Before the plant food present in the green manure crop is available for the growing crop that succeeds it, the plant tissue of the green manure crop has to be broken down into simpler compounds and elements by the decay-producing bacteria, and these simpler compounds and elements recombined by other kinds of bacteria. Thus, with the delay in ploughing in order to get a heavier crop to plough in, we have a shorter time for the decay of the green manure crop between the times of ploughing and subsequent planting. Sufficient time must be allowed for the decomposition of the sweet clover after it is ploughed in, if best results are to be obtained.

The season was a fair one for growth. There were twelve showers fairly well distributed over the period, averaging 0.35 inches per shower and totalling 4.24 inches rainfall. The average daily temperature for May was 50.3°F., the highest daily average being 75.5°F. and the lowest 39.5°F. The average daily temperature for June 1st to 17th inclusive was 57°F., the highest daily average being 72°F and the lowest 44°F. These meteorological figures were obtained from the records of the Department of Agricultural Economics, Ontario Agricultural College.

On July 10th, three and a half weeks after the last preceding nitrogen determination was made, the crop was being ensiled.

It was considered to be of interest to make another nitrogen determination at this date, although this procedure did not form part of the original investigation.

Accordingly, five average plants were selected, and determinations made as before.

Average height of plant tops.....	5	feet
Weight of tops.....	92	grams
Amount of N ₂ per gram.....	0.0406	"
Total amount of N ₂ of tops.....	3.7352	"
Average length of roots.....	13	inches
Weight of roots	12.2	grams
Amount of N ₂ per gram.....	0.0266	"
Total amount of N ₂ of roots.....	0.3245	"
Amount of N ₂ per gram of Tops and roots.....	0.0672	"
Total amount of N ₂ of tops and roots.....	4.0597	"
Pounds of N ₂ per acre of crop based on the factor of five plants per sq. yard.....		215.7 lbs.

SUMMARY

The nitrogen content of a sweet clover crop that was intended for green manure was determined weekly from April 26th until June 17th to ascertain the advisability of leaving the crop as long as possible before ploughing it in on account of increase of nitrogen.

From April 26th to May 23rd there was an increase of total nitrogen from 13.8 to 76.1 pounds per acre. During the next three weeks this amount of nitrogen was again nearly doubled, rising from 76.1 to 133.1 pounds per acre.

The percentage of this nitrogen that was obtained from the atmosphere was not determined.

HYPOTHESES NOUVELLES SUR LE MODE D'ACTION DE LA POTASSE.

ALBERT BRUNO

Ex-Inspecteur général des Stations agronomiques, Mulhouse, France.

Dans les premières études relatives à l'emploi et à l'efficacité des engrais chimiques, on s'est préoccupé surtout de constater les résultats obtenus à la récolte par l'emploi de quantités variables d'éléments fertilisants. De nombreux auteurs ont ensuite étudié la marche de l'absorption des éléments fertilisants au cours de la végétation. C'est surtout dans les années récentes qu'on s'est attaché à pénétrer plus intimement le mécanisme d'action de chacun des éléments en question.

En ce qui concerne la vigne, chacun connaît la méthode originale créée par le professeur Lagatu, qui permet d'exercer, à tout moment de la végétation, un contrôle sur les feuilles qui constituent le laboratoire actif de la plante.

On sait que les physiologistes et les phyto-pathologues ont utilement multiplié les observations et les expériences, et qu'ils ont pu ainsi (M. Ravaz pour le rougeot de la vigne) caractériser l'action très efficace du potassium pour assurer la santé de la plante. Des physiologistes purs, comme M. Blaringhem, se sont attachés à observer l'action des éléments fertilisants sur le développement de quelques plantes aux divers stades de leur croissance. Il y a lieu de fonder de grands espoirs sur l'ensemble de ces études qui ne se contentent plus d'un résultat final, mais qui s'efforcent vers la connaissance réelle de l'action particulière à chacun des éléments fertilisants pendant le cours de la vie des plantes cultivées.

Dans un ordre d'idée tout différent, et que nous allons résumer ci-après, certains travaux scientifiques modernes ouvrent la voie à des études dont le but est de pénétrer d'une façon encore plus complète le mode d'action des aliments de la plante. Ces études nouvelles ne trouvent plus une base suffisante dans la chimie proprement dite et se rattachent aux travaux les plus récents de la physique. En particulier le mode d'action du potassium—nettement différent de celui de l'azote ou du phosphore pour lesquels on connaît des formes chimiques insolubles dans la substance des végétaux cultivés—fait l'objet d'investigations vraiment intéressantes.

On a observé, à Rothamsted notamment, que, dans les années où l'insolation est insuffisante, une bonne fumure potassique permet aux plantes d'assimiler cependant une quantité suffisamment élevée de carbone atmosphérique. D'autre part, les études relatives à la répartition du potassium dans la plante en voie de croissance font ressortir que cet élément est particulièrement abondant dans les organes où se font activement la fabrication et l'accumulation des hydrates de carbone, c'est-à-dire dans les cellules foliaires les plus actives et dans les fruits. La présence du potassium est donc directement liée à l'énergie de la fixation du carbone sous l'action des rayons solaires. Non seulement le potassium augmente la quantité totale de chlorophylle à l'hectare, mais il stimule l'activité des éléments chlorophylliens, et permet, ainsi qu'on l'a constaté, une fixation plus importante de composés hydrocarbonés à égalité d'insolation.

D'autre part, on sait que le potassium possède une radio-activité liée à l'atome lui-même puisque tous les sels de potassium sont radio-actifs et produisent un courant d'ionisation proportionnel à leur teneur en potassium (Campbell et Wood). On sait encore, d'après Henriot et Vavon, que les rayons émis par le potassium sont déviables par l'aimant, portent une charge négative; ce sont des rayons β , des électrons. Ces derniers partent de l'atome avec une vitesse d'environ 200,000 km. par seconde, ils sont particulièrement pénétrants et traversent même les corps solides. A poids égal, un sel de potassium est mille fois moins actif que le sel d'uranium correspondant.

Il était donc plausible d'invoquer, pour expliquer le rôle du potassium, soit une action catalytique, soit la radio-activité; mais autant qu'on sache à présent (Stoklasa), une faible radio-activité stimule la croissance à l'obscurité et la ralentit à la lumière. On se trouve donc conduit à admettre qu'il s'agit d'une action un peu différente.

On sait encore depuis quelques années, d'après les travaux de F. W. Ashton et de ses élèves, qu'il y a en réalité deux potassiums, deux (isotopes) ayant les mêmes propriétés chimiques générales, mais possédant comme poids atomiques respectifs 39 et 41. Tout récemment, von Hevesy et Marie Lögstrup ont réussi une distillation augmentant la proportion de K 41 dans le mélange naturel K 39 et de K 41 — simultanément la radio-activité se trouve augmentée, et l'on doit ainsi attribuer à K 41 la radio-activité du potassium.

Ceci posé, il n'est pas surprenant que le professeur Binz, de Berlin, n'hésite pas à dire que, sans doute, les plantes vertes ayant besoin, pour leur croissance de matières premières et d'énergie, tirent cette énergie non seulement de la lumière, mais encore du dégagement des électrons du potassium à l'intérieur du végétal.

Plus récemment, dans le même ordre d'idées, le docteur Jacob a appelé l'attention sur le fait que la réaction qui se produit à la température ordinaire dans les feuilles :—



est difficilement expliquée par la seule action de la radiation solaire. Le docteur Jacob en vient ainsi à considérer que le potassium agirait, non plus seulement à la manière d'un élément matériel constitutif de la plante, mais comme un moteur recevant l'énergie de la radiation solaire et livrant une énergie beaucoup plus intense, celle d'un bombardement par les particules.

Il s'agirait suivant cette théorie—tout au moins cette hypothèse—d'un photo effet du potassium, non seulement utile mais indispensable pour la synthèse chlorophyllienne qui est, on le sait, la source de toute matière hydro-carbonée et, en particulier, pour la vigne, du sucre des raisins qui donnera au vin son alcool et sa liqueur, des matières pectiques nécessaires à son velouté, du tanin, de l'acide tartrique, des produits odorants ou sapides, que les analystes ont réussi déjà à séparer et à caractériser, et aussi sans doute des éléments nombreux dont la petite quantité échappe encore aux investigations du laboratoire, mais qui constituent en somme la différence entre les vins de grande qualité et les vins ordinaires.

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MEMBRES DE LA C.S.T.A. DECORES PAR LE
GOUVERNEMENT FRANCAIS.

Il y a quelque temps nous signalions le voyage au Canada d'un groupe de professeurs et d'élèves de l'Ecole Nationale d'Agriculture française de Grignon. A la suite de ce voyage le Gouvernement français a décoré de l'Ordre du Mérite Agricole un certain nombre de Canadiens et de résidents du Canada dont les efforts ont largement contribué au succès du voyage.

ONT ETE NOMMES

Au grade d'Officier de l'Ordre du Mérite Agricole:

- L'Hon. J. L. Perron, Ministre de l'Agriculture de la Province de Québec;
 M. Edouard Montpetit, Secrétaire de l'Université de Montréal;
 M. A. Tarut, de la Maison O'Brien & Williams, Président du Comité France-Amérique de Montréal;

Au grade de Chevalier de l'Ordre du Mérite Agricole:

- Mgr. Allard, Curé de Ste-Martine,
 le Dr. A. T. Charron, Sous-Ministre Adjoint de l'Agriculture, Ottawa;
 M. A. A. Gardiner, Directeur-Général Adjoint du Service des Passagers aux Chemins de Fer Canadiens Nationaux;
 Dr. R. Harcourt, Professeur au Collège d'Agriculture de l'Ontario, Guelph, Ont.;
 M. J. Henri Lavoie, Chef du Service de l'Horticulture, Ministère de l'Agriculture, Québec;
 le R. P. Leopold, Directeur de l'Institut Agricole d'Oka.

Plusieurs des nouveaux décorés (le Dr. Charron, le Dr. Harcourt, M. Lavoie, le R. P. Léopold) sont membres de la C.S.T.A. et nous félicitons vivement nos confrères du témoignage d'honneur dont ils viennent d'être l'objet. En les honorant, c'est non seulement sa reconnaissance que le Gouvernement français a voulu exprimer à ceux qui ont facilité la tâche de la mission d'étude de Grignon, c'est aussi une marque d'estime qu'il a voulu donner à ceux qui prennent à coeur le développement de l'agriculture canadienne et qui par leur dévouement à la cause agricole, qu'elle soit du Canada ou d'ailleurs, s'imposent à l'admiration des techniciens agricoles du monde entier.

CONCERNING THE C.S.T.A.

NOTES AND NEWS

Robert Newton (McGill '12), Professor of Field Crops and Plant Biochemistry at the University of Alberta, is acting head of the division of economic biology and agriculture for the National Research Council of Canada.

C. L. Huskins (Alberta '23) has been elected a Fellow of the Linnean Society of London, England, and a member of the Society for Experimental Biology.

Marc H. Hudon (Laval '25) recently appointed Technical Advisor of the Chateau Cheese Co., Ltd., Ottawa, has now been elected a Vice-president of that organization.

T. W. L. Burke (Saskatchewan '23), formerly Dominion Seed and Feed Inspector at Winnipeg, Man., has been appointed Supervising Analyst at Saskatoon, Sask. His mailing address is Dominion Seed Branch, 610 Ross Building, Saskatoon, Sask.

B. H. Wilson (Alberta '27), who has been taking graduate work at the University of Minnesota, is now at the Dominion Experimental Farm, Indian Head, Sask.

P. A. Dorion (Montreal '27) has been appointed Agricultural Representative under the Ontario Department of Agriculture for the Sudbury District, with headquarters at Sudbury, Ont.

W. G. McGregor (Toronto '24), who has been taking graduate work towards a Ph.D. degree in genetics and plant pathology at the Iowa State College, is now on the staff of the Cereal Division, Central Experimental Farm, Ottawa, Ont.

J. H. Tremblay (Laval '17) has been appointed Agricultural Representative under the Ontario Department of Agriculture at Kapuskasing, Ont.

H. M. McElroy (Toronto '13), formerly District Manager for Northwestern Ontario of the Ontario Equitable Life and Accident Insurance Co., has received the appointment of Manager for the Company at Calgary, Alta.

D. Limoges (Montreal '25) has changed his address to Ste. Thérèse, Terrebonne Co., P.Q.

W. B. Gornall, formerly Assistant to Dominion Fruit Commissioner, has been appointed Chief, Extension of Markets Division, Dominion Fruit Branch, Ottawa, Ont.

J. H. Lauziere (Laval '15), who has been County Agriculturist for Arthabaska County, P.Q. since 1918, has received the appointment of District Inspector of County Agriculturists (District No. 5) with headquarters at Cookshire, P.Q.

Jules Simard (McGill '12), District Seed and Feed Inspector for the Maritime Provinces since 1927, has returned to the same position in the Province of Quebec. He was District Inspector in Quebec from 1912 until 1927. G. LeLacheur (McGill '13) is acting District Inspector for the Maritime Provinces,

APPLICATIONS FOR MEMBERSHIP

The following applications for regular membership have been received since January 2, 1930:—

- de Broin, J. (The Sorbonne, 1924, B.A.) Montreal, P.Q.
Girard, H. (Laval, 1927, B.S.A.) St. Anselme, P.Q.
Robertson, H. T. (Saskatchewan, 1928, B.Sc., 1929 M.Sc.) Edmonton, Alta.
Robinson, V. B. (Alberta, 1920, B.S.A.) Vancouver, B.C.
Taggart, J. G. (Toronto, 1912, B.S.A.) Swift Current, Sask.
Thomson, S. G. (Alberta, 1929, B. Sc. Agr.) Edmonton, Alta.
Warren, W. H. (Toronto, 1929, B.S.A.) Guelph, Ont.
Western, H. U. (Toronto, 1922, B.S.A.) Barrie, Ont.
Whiteside, G. B. (Toronto, 1929, B.S.A.) Guelph, Ont.

CANADIAN PHYTOPATHOLOGICAL SOCIETY

The above Society, organized in December last, is now inviting all those who are interested in plant pathology to join as charter members. The invitation closes on March 1st, 1930, and applications received after that date cannot be considered until the first annual meeting of the Society in June, 1931. Those who desire to become charter members should make application at once to the Secretary, Mr. T. G. Major, Central Experimental Farm, Ottawa, Ont. The annual fee is \$3.00.

C.S.T.A. EMPLOYMENT BUREAU

The attention of members is directed to the advertising pages of this issue, in which three commercial openings are announced. It is intended to place the services of this Bureau at the disposal of all employing institutions and if full co-operation is obtained, it should develop into an important C.S.T.A. activity.

THE JUNE CONVENTION

Members of the Society who are at all likely to attend the annual meeting at Wolfville, N.S., and particularly members in Ontario and the four western provinces, should notify the General Secretary at once. *This is highly important.* There are many details in connection with transportation and with reception arrangements that will be greatly facilitated if this assistance is given by members.

MEMBERSHIP FEES

Members who have not yet paid their fees for the current year, ending on May 31, 1930, should do so at once. Since the Society's incorporation in 1928, it has become necessary to remove from the active membership list the names of those whose fees are not paid within a reasonable time after their due date. Eight months of the current year have now elapsed.

LIST OF MEMBERS

A complete alphabetical list of members of the Society, with their official title and address, will be printed early in May next and mailed to every member. New members whose applications are received prior to April 15th will be included in the list. Similar lists were published in 1926, 1927 and 1928; the list was not published in 1929, being replaced by the more extensive "Who's Who," issued every five years.

At the end of January the total membership of the Society was 1,140, and it is hoped that the number will be increased to 1,200 before the 1930 list is published in May .

T. EATON COMPANY SCHOLARSHIPS

Announcement is made in the advertising pages of this issue of the 1930 scholarships awarded through the Society by the T. Eaton Company. It will be noted that instead of the five scholarships of \$600 awarded in 1928 and 1929, there are four scholarships of that amount and one of \$1200, the latter tenable in Great Britain. This is made possible by the fact that one of the 1929 scholarships was not taken up and is now being added to the \$3,000 scholarship grant for 1930 to establish a \$1,200 award. The arrangement meets with the full approval of the donors.

FREDERICK HUGH GRINDLEY, General Secretary-Treasurer of the C.S.T.A., died shortly before midnight at his home, 258 Laurier Avenue West, on Friday, February 14th. On April 28th he would have celebrated his 41st birthday. He was taken ill on December 2nd, 1929, with typhoid fever and shortly after was moved to the Civic Hospital where he remained until New Year's Eve. Returning to his home he soon recovered sufficiently to attend to his office duties when he suffered a relapse and pleurisy developed. From this second malady he was believed to be recovering when he suddenly expired.

Mr. Grindley was born at Massawippi, P.Q., in 1889, son of Arthur W. Grindley, who was one of the first students to enter the Ontario Agricultural College, and grandson of R. R. Grindley, a former General Manager of the Bank of British North America.

Fred received his early education in Cheltenham, England, his father at the time being Chief Inspector to the Canadian Government under Lord Strathcona, then Canadian High Commissioner. He returned to Canada in 1907 and enrolled as a student at Macdonald College, thus repeating the history of his father who, as already intimated, was among the first students to enter the Ontario Agricultural College. Graduating from McGill with the B.S.A. degree in 1911, he was secretary of the Dominion inquiry into fruit growing conditions in Canada in 1911-12; Assistant Chief, Fruit Division, Dominion Department of Agriculture, Ottawa, 1912-14; Assistant Dominion Fruit Commissioner 1914-20; Secretary, Fruit and Vegetable Committee, Canada Food Board, 1917-18; and since 1920 General Secretary of the C.S.T.A. and Managing Editor of *Scientific Agriculture*.

Frederick Hugh Grindley



Fred Grindley is dead. In these few terse words over the telephone during the ebbing hours of St. Valentine's Day came the tragic news of the passing, not only of a very dear friend, but of one who more than anyone else has contributed to the upbuilding of the C.S.T.A. Just when we were hoping against hope that the thing most feared would not materialize, and that he would be spared many more years for useful service, came the portentous message announcing the end.

Any attempt to measure the extent of our personal loss or of the loss to the Society of its General Secretary—its guiding spirit—would be entirely futile. This is something which every member must feel but cannot adequately express. All who knew him loved him. All who knew of his work and what he had accomplished in ten short years worshipped at his footstool. For the C.S.T.A. as we know it today—the giant oak developed from the tiny acorn—is Fred Grindley. Every member of our Society will ungrudgingly concede this. Many will recall how he stood forth almost alone, inimitable, indomitable, during those early years when things seemed blackest and when there were few to help carry the load. Such genius, such devotion, such zeal and withal such an uncanny understanding of human nature and of human frailties! His was the most inspiring soul among us all, irradiating the nobility of industry and of faith in a great cause. Spurning opportunities for financial advancement in other fields he remained at his post, confident in the ultimate consummation of a great enterprise.

And what of the future? Do we who remain not owe it to his memory to carry on and do our best to perfect the splendid structure, in the laying of whose foundations he played so large a part? Could we erect to his memory a more fitting monument or could we pay him a greater tribute? Let us then like old "Michael" of the sheepfold, immortalised by William Wordsworth, look upon the Society as "a covenant between us", inspiring us to greater and greater efforts with each succeeding year.

Just as he wrote, following the greatly lamented death of George Creelman, "it is comforting to know that he was bright and happy the evening before he died", so is it a grateful memory to recall that Fred's last evening on earth was a particularly happy one and that the end came without prolonged suffering.

To Mrs. Grindley, who has been a devoted helpmate and who has contributed so substantially and unselfishly to the welfare of our Society since its inception, every member of the C.S.T.A., English and French alike, extends his most sincere sympathy.

L. H. N.



FRED. H. GRINDLEY

Frederick Hugh Grindley

C'est avec une profonde douleur que les membres de la Société Canadienne des Techniciens Agricoles ont appris le décès de Fred Grindley survenu brusquement à Ottawa dans la nuit du 14 au 15 février. On se souviendra qu'au cours d'un voyage au cours duquel ils avaient visité presque toutes les sections de l'Est, le Président et le Secrétaire Général de notre association avaient tous deux contracté la fièvre typhoïde. Après plusieurs mois d'anxiété tous deux avaient été déclarés hors de danger, et juste à ce moment, quand chacun s'attendait à le voir reprendre son travail, la mort brusquement est venue arracher Fred Grindley à l'affection de sa famille et de ses amis. Que Mme Grindley, que toute sa famille veuillent bien trouver ici l'expression émue de notre sympathie. Nous ressentons vivement la perte que les siens ont subie, et savons trop, hélas, combien irréparable elle est.

Depuis la fondation de notre société en 1920, Fred Grindley en avait été le secrétaire général. Dire son dévouement à la cause de la société est chose impossible. Il en était l'âme et le cerveau. Il avait l'invincible enthousiasme qui fait accomplir les grandes choses. Dans toutes les périodes difficiles, dans tous les moments critiques, à travers tous les dangers courus par la Société dans ses périodes d'enfance et d'adolescence, c'est le courage tenace de Fred Grindley, son inébranlable foi dans l'avenir des techniciens agricoles, qui sauvèrent la Société. C'est lui qui en fit l'association forte, et consciente de sa force, qu'elle est aujourd'hui. En fait, quiconque pensait à la C.S.T.A. pensait d'abord à Fred Grindley. La Société était plus que son oeuvre, elle était sa vie tout entière; et, pour tous les membres, Fred était, plus que le secrétaire de l'association, un ami personnel que l'on était toujours content de revoir. Il combinait la largeur de vues d'un savant avec le sens pratique d'un homme d'affaires, il était à son aise avec tous et dans toutes les circonstances. Ici, dans la Province de Québec, les membres de langue française le considéraient comme l'un des leurs. Qui ne se souvient du soin avec lequel il préparait ses discours et ses rapports, quand il venait rendre visite aux sections de Ste Anne, de Québec ou de Montréal, pour s'entretenir avec ses collègues dans leur propre langue? Quand la stupéfiante nouvelle de sa mort fut connue, pur chacun ce fut un jour de deuil.

Ses derniers mots furent pour la tâche qu'il lui restait à terminer. C'est à nous, qui l'avons perdu, de voir que son travail et sa vie n'aient pas été en vain. D'un bout à l'autre du Canada, il a rendu les techniciens agricoles conscients d'eux-mêmes, de leur valeur, de ce qu'ils représentent pour le pays tout entier. Il nous reste maintenant à faire accepter les mêmes idées dans tous les milieux. Il nous faut travailler pour maintenir haut dans le monde le prestige des techniciens agricoles, pour prendre et garder la place au soleil qui nous revient. Nous le devons non seulement à nous-mêmes, mais à la classe agricole toute entière dont nous sommes un peu les représentants et même les dirigeants, nous le devons aux universités dont nous sommes sortis, nous le devons à la mémoire de Fred Grindley; car c'est en faisant notre devoir vis-à-vis des vivants que nous rendrons le plus bel hommage à ceux qui meurent à la tâche à nos côtés.

H.E.L.

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A RECONCILING SPIRIT

An Address delivered by the Rev. A. Robert George in the First Baptist Church, Ottawa, on Monday, February Seventeenth, 1930.

Fred Grindley's short life is over, his work is done,—but nobly done! Many a man comes to fourscore years and knows not why he was born; here was one who amply justified existence. He was fortunate to find his task and he did it with his might. He was that rare thing among us, a man of a reconciling spirit; as it seems to us of a more impetuous temper, a kind of miraculous man who could unite far-sundered interests. What statesmen did at Confederation in high politics he did for scientific agriculture. He was a man of continental vision with hands so sensitive that he was able to handle his materials without breaking them. I, who only knew and rejoiced in him as friend, can well imagine how he would do it; the charm of him, disarming a too alert suspicion, the pleasant laugh discounting the too harsh criticism, the shrewdness that appealed to the practical man and the kindling vision that appealed to the idealists among you, the while his fairness of judgment was winning the confidence of conflicting parties.

I think of his glee as he came to me one night with the good news that he had secured the funds to establish the Association in fairer quarters, together we drew up the plans for the new offices the central feature of which must be a room where men could get together in friendly intercourse. Again and again he insisted that whatever else went that room must be of the proportions and furnishings that would make it easy for men to be at ease with each other. There now they stand, a symbol of his judgment and goodwill, where his spirit is housed, that spirit by which alone great enterprises may be carried on.

We give God thanks for this generous, kindly man. It was always a good hour in which we met him and when he had passed the step was firmer and the heart a little warmer. Now we have met him for the last time on earth but surely we shall not leave him with the mere coldness of death, but rather with the thought of his high and valourous spirit; to some of you, at any rate, he has left a legacy of goodwill and high enterprise that you dare not neglect; by the memory of Fred Grindley you are pledged to carry it to nobler fulfilment.
